
MA300 EMG System

User Guide



By Motion Lab Systems, Inc.

This manual was written by Motion Lab Systems using *ComponentOne Doc-To-Help*.™

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Important Information

Warranty

In no case shall Motion Lab Systems, Inc be liable for any consequential or incidental damages for breach of this or any other warranty, express or implied.

Consumable items (such as preamplifiers, cables etc) are warranted for 30 days from initial use.

Motion Lab systems, Inc., warrants that each MA300 system, comprising of the Desk Top Unit and Back-Pack Unit will be free from defective materials and construction for twenty-four (24) months from the date of installation.

Motion Lab Systems, Inc., agrees to correct any of the above defects (parts and labor only) when the complete system is returned to the factory freight prepaid by the customer. Return authorization must be obtained from Motion Lab Systems before returning the system to the factory. The repaired system will be returned to the customer freight prepaid during the warranty period. Hardware Service Contracts are available to extend this warranty. Under this warranty Motion Lab Systems may, at its option, repair or replace the defective system or system components.

This warranty will be invalid if, in the sole judgment of Motion Lab Systems, the system has been subjected to misuse, abuse, neglect, accident, improper installation or application, alteration or neglect in use, storage, transportation or handling.

The preamplifiers, cables, event switches and other items that may be supplied with the backpack and desktop unit are considered to be consumable items and are warranted to 30 days from initial use. These items are considered to have a limited life and should be replaced when necessary. Additional foot switches, pre-amplifiers and cables may be ordered directly from Motion Lab Systems or your distributor.

Intended Use

The Motion Lab Systems, Inc., MA300 EMG system is designed for Clinical, Investigational, Scholarship and Research use and may be used in the treatment and diagnosis of human beings.

All MA300 systems have received US FDA 510(k) clearance (Sec. 890.1375) for use as a diagnostic electromyograph with human beings. A diagnostic electromyograph is defined by the US FDA as:

A diagnostic electromyograph is a device intended for medical purposes, such as to monitor and display the bioelectric signals produced by muscles, to stimulate peripheral nerves, and to monitor and display the electrical activity produced by nerves, for the diagnosis and prognosis of neuromuscular disease. [21CFR890.1375]

Mandatory Warnings

Read Manual before Use

The MA300 is an AC line powered device - make sure that you read this manual (User Manual) before operating the MA300 EMG system or connecting the MA300 system to any other device.

Warning – High Voltage Inside

CLASS I EQUIPMENT energized from an external power source as defined by UL 60601-1.

TYPE BF protection from electrical shock as defined by UL 60601-1.

Unauthorized personnel must not disassemble the MA300 Desk Top Unit without taking the appropriate precautions to ensure safety.

Warning - Connect to a Grounded Outlet Only!

Safe and effective operation of this device requires a three wire AC power connection with an electrical ground (earth) connection.

SIP/SOP Connections

Accessory equipment connected to the analog and digital interfaces must be certified according to the respective IEC standards (i.e. IEC 950 for data processing equipment and IEC 601-1 for medical equipment). Furthermore all configurations shall comply with the system standard IEC 601-1-1.

Everybody who connects additional equipment to the signal input part or signal output part configures a medical system, and is therefore responsible that the system complies with the requirements of IEC 601-1-1. If in doubt, consult the technical services department or your local representative.

Fuse Replacement

The MA300 Desk Top Unit uses 500mA/250V SLO-BLO fuses only.

In the event of a fuse requiring replacement you must replace the AC line fuses with 500mA/250V SLO-BLO fuses to maintain protection.

Maintenance

The MA300 system is designed to be maintenance free and does not require any regular maintenance to ensure safe and effective operation.

Cleaning

The surfaces of the MA300 system and preamplifiers may be cleaned and sterilized with a damp cloth and mild detergent or with isopropyl alcohol swabs. The MA300 System is NOT SEALED. DO NOT IMMERSE IN WATER OR ANY OTHER SOLUTION. The MA300 system is not designed for use in a sterile environment. DO NOT subject the MA300 system to any sterilization procedure.

Anesthetic Environment

The MA300 is not suitable for use in the presence of a FLAMMABLE ANAESTHETIC MIXTURE WITH AIR OR WITH OXYGEN OR WITH NITROUS OXIDE or in the presence of other explosive gases or vapors.

Contraindications

DO NOT USE on irritated skin or open wounds.

Discontinue use immediately if skin irritation or discomfort occurs.

Use with HF Surgical Equipment

Connection of a patient to HF surgical equipment and to an electromyograph or evoked response equipment simultaneously may result in burns at the site of the electrical stimulator or biopotential input part electrodes and possible damage to the electrical stimulator or biological amplifiers.

Additional Documentation

Motion Lab Systems will make the following items available on request; circuit diagrams, component parts lists, descriptions and calibration instructions. Please contact Motion Lab Systems, Inc. or your local distributor for further information.

FCC Regulatory Information – MA300-DTU

Product Information

Product Name	Motion Lab Systems EMG System
Model Number	MA300
FCC Rules	Tested To Comply With FCC Part 15, Class B
Operating Environment	For Home Or Office Use

FCC Compliance Statement

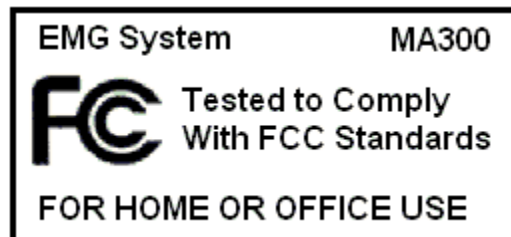
This equipment complies with Part 15 of the FCC Rules. Operation is subject to the following conditions: (1) this device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

Information to the User

This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to Part 15 of the FCC rules. These limits are designed to provide reasonable protection against harmful interference in a residential or office installation. This equipment generates, uses, and can radiate radio frequency energy and if not installed and operated in strict accordance with the manufacturer's instruction, may cause interference to radio communications. However, there is no guarantee that interference will not occur in a particular situation. Interference can be determined by turning the equipment off and on while monitoring radio or television reception. The user may be able to eliminate any interference by implementing one or more of the following measures:

- Reorient the affected device and/or its receiving antenna.
- Increase the distance between the affected device and the equipment.
- Plug the equipment and any peripheral equipment into a different branch circuit from that used by the affected device.
- If necessary, consult an experienced technician for additional suggestions.

Caution: Changes or modifications to the electronics or enclosure to this unit that are not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.



FCC Regulatory Information – MA300-RTT

RF Transmitter Installation Instructions

The MA300-RTT transmitter should only be installed by qualified service personnel. The transmitter connects to the MA300 BPU unit with the supplied LEMO cable. It supplies power to the BPU from its internal rechargeable battery.

INSTALLATION INSTRUCTIONS

1. Connect the MA300RTT transmitter to the BPU. Ensure that the battery of the MA300RTT is fully charged and press the power switch. The LED lights should indicate the presence of the digital signal from the BPU and the battery charge state.
2. Select a channel that does not conflict with other MA300-RTT units by setting the rotary switch. The MA300-RTR receiver should be connected to the DTU and must have its channel select switch set to the same channel as the MA300-RTT transmitter. The MA300-RTR receiver is powered by the DTU and does not need an external power supply.
3. If possible, avoid installing MA300-RTT in areas near large metallic objects such as air conditioners, heaters, screens and heaters.

FCC NOTICE

The Model MA300-RTT transmitter generates and uses radio frequency energy. If not installed and used in accordance with the manufacturer's instructions, it may cause interference to radio and television reception. The transmitter has been tested and found to comply with the specifications in Part 15 of FCC Rules for Intentional Radiators and FCC Part 15 Subpart C, Specifications.

If this equipment causes interference to radio or television reception - which can be determined by turning the equipment on and off - the installer is encouraged to correct the interference by one or more of the following measures: 1) Reorient the antenna of the radio/television. 2) Connect the MA300 DTU to a different outlet so the control panel and radio/television are on different branch circuits. 3) Relocate the control panel with respect to the radio/television.

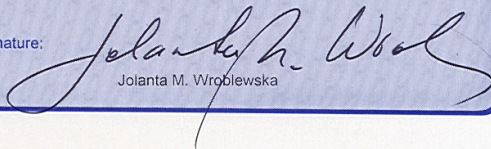
If necessary, the installer should consult an experienced radio/television technician for additional suggestions, or send for the "Interference Handbook" prepared by the Federal Communications Commission. This booklet is available from the U.S. Government Printing Office, Washington, D.C., 20402. Stock number 004-000-00450-7.

CAUTION: No field changes or modifications to the MA300-RTT should be made unless they are specifically covered in this manual.

All adjustments must be made at the factory under the specific guidelines set forth in our manufacturing processes. Any modification to the equipment could void the user's authority to operate the equipment and render the equipment in violation of FCC Part 15, Subpart C, 15.247.

This device complies with Part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) this device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

CB Test Certificate

INTERNATIONAL ELECTROTECHNICAL COMMISSION (IEC) COMMISSION ELECTROTECHNIQUE INTERNATIONALE (CEI)		Ref. Certif. No. US/5657/UL
IEC SYSTEM FOR CONFORMITY TESTING AND CERTIFICATION OF ELECTRICAL EQUIPMENT (IECEE) CB SCHEME		SYSTEME CEI D'ESSAIS DE CONFORMITE ET DE CERTIFICATION DES EQUIPEMENTS ELECTRIQUES (IECEE) METHODE OC
CB TEST CERTIFICATE CERTIFICAT D'ESSAI OC		
Product <i>Produit</i>	Multi-Channel EMG System	
Name and address of the applicant <i>Nom et adresse du demandeur</i>	Motion Lab Systems, Inc. 4326 Pine Park Drive Baton Rouge, LA 70809, USA	
Name and address of the manufacturer <i>Nom et adresse du fabricant</i>	Motion Lab Systems, Inc. 4326 Pine Park Drive Baton Rouge, LA 70809, USA	
Name and address of the factory <i>Nom et adresse de l'usine</i>	MDCO Inc., DBA Electronic Mfg. Co. 13340 Wright Circle Tampa, FL 33626, USA	
Rating and principal characteristics <i>Valeurs nominales et caractéristiques principales</i>	Input: 100-240 V ac, 50-60 Hz, 40 VA	
Trademark (if any) <i>Marque de fabrique (si elle existe)</i>	Motion Lab Systems, Inc.	
Model / Type Ref. <i>Ref. de type</i>	MA-300	
Additional information (if necessary) <i>Information complémentaire (si nécessaire)</i>	The CB Test Report comprises 7 Enclosures.	
A sample of the product was tested and found to be in conformity with <i>Un échantillon de ce produit a été essayé et a été considéré conforme à la</i>	PUBLICATION EDITION IEC 60601-1 (1988) Second Edition with Amendment No. 1 (1991) and No. 2 (1995). Additionally evaluated to IEC 60601-2-40.	
as shown in the Test Report Ref. No. which forms part of this Certificate <i>comme indiqué dans le Rapport d'essais numéro de référence qui constitue partie de ce Certificat</i>	00RT6519A-11092001	
This CB Test Certificate is issued by the National Certification Body <i>Ce Certificat d'essai OC est établi par l'Organisme National de Certification</i>		
 Underwriters Laboratories Inc.®		Underwriters Laboratories Inc. / International Compliance Services 333 Pfingsten Road, Northbrook, IL 60062-2096 United States of America TEL INT* 1-847-272-8800, Ext. 43008 FAX INT* 1-847-272-9562 email: jolanta.m.wroblewska@us.ul.com
Date: Issued: 28 January 2002	Signature:  Jolanta M. Wroblewska	
Issued 08-2000		

Declaration of Conformity



Declaration of Conformity

Manufacturers Name:
Manufacturers Address:

Motion Lab Systems, Inc.
15045 Old Hammond Highway,
Baton Rouge, LA 70816 USA

declares that the product:

Product Name:

Electromyography Device

Model Number:

MA-300

conforms to the following standards:

Safety:

IEC 60601-1 (1988) Second Edition
With Amendment No 1 (1991) and No 2 (1995).
IEC 60601-2-40

EMC:

Medical Device Directive
IEC 60601-1-2 : 1993
IEC 801-2 : 1991
IEC 801-3 : 1984
IEC 801-4 : 1998
IEC 1000-4-5 : 1995
EN 6000-4-5 : 1995
EN 55011 : 1991 Group 1, Class B

The product is in conformity with the requirements of the Low-Voltage Directive (73/23/EEC) and the EMC Directive (89/336/EEC).

European Contact:

Motion Lab Systems, Ltd,
Green Acres, Templebar Rd. Pentlepoir
Pembrokeshire SA680RA
Email: eu.support@motion-labs.com

A handwritten signature in black ink, appearing to read 'Edmund Cramp'.

Edmund Cramp, President
Motion Lab Systems, Inc. Baton Rouge, USA
January 1, 2012

International Standards

Canada

CSA C22.2 NO 601.1-M90 Medical Electrical Equipment - Part 1: General Requirements for Safety General Instruction No 1: Supplement 1; 1994 R (1997).

This digital apparatus does not exceed the Class B limits for radio noise emissions from digital apparatus set out in the Radio Interference Regulations of the Canadian Department of Communications.

Le present appareil numerique n'emet pas de bruits radioelectriques depassant les limites applicables aux appareils numeriques de la class B prescrites dans le Reglement sur le brouillage radioelectrique edicte par le ministere des Communications du Canada.

European Community

CENELEC EN 60601-1 - Medical Electrical Equipment Part 1:

IEC 60601-2-40 - Particular Requirements for Electromyographs and Evoked Response Equipment.

General Requirements for Safety Incorporates Corrigendum July 1994; Includes Amendments A1: 1993, A11: 1993, A12: 1993, A2: 1995 and A13:1996; IEC 601-1: 1988 + A1: 1991 + A2: 1995 +

CENELEC EN 60601-1-2 - Medical Electrical Equipment Part 1: General Requirements for Safety 2. Collateral Standard: Electromagnetic Compatibility - Requirements and Tests (IEC 601-1-2: 1993) - EMISSIONS

CENELEC EN 60601-1-2 - Medical Electrical Equipment Part 1: General Requirements for Safety 2. Collateral Standard: Electromagnetic Compatibility - Requirements and Tests (IEC 601-1-2: 1993) – IMMUNITY

EU Contact: Motion Lab Systems, Ltd. Green Acres, Templebar Rd. Pentlepoir, Kilketty, Pembrokeshire, SA680RA

Type of Equipment: EMG System.

Manufacturer: Electronic Manufacturing Co., 13440 Wright Circle, Tampa, FL 33626 USA. Telephone: +1 (813) 855-4068

Responsible Party: Motion Lab Systems, Inc., 15045 Old Hammond Hwy, Baton Rouge, LA 70816 USA. Telephone: +1 (225) 272-7364

<http://www.motion-labs.com>

United States of America

UL 2601-1 - UL Standard for Safety Medical Electrical equipment, Part 1: General Requirements for Safety Second Edition.

The MA300 system and pre-amplifiers have received US FDA 510(k) clearance (Sec. 890.1375) for use as a diagnostic electromyograph for medical purposes with human beings. The preamplifier device listing is D143183, FDA510(k) K974385 and the MA300 system listing is E443972, FDA510(k) K000220.

Our FDA Establishment Registration number is 2320542.

Introduction

Features

All MA300 systems have received US FDA 510(k) clearance (Sec. 890.1375) for use as a diagnostic electromyograph for medical purposes on human beings.

Welcome to the User Guide for the Motion Lab Systems MA300 Electromyography systems. These are a range of high quality EMG systems intended for use in the investigation of the physiological process involved in muscle contraction and can be used to record multiple channels of EMG data from human beings in a clinical environment - either as a stand-alone system, or with a motion capture or gait analysis system. These systems enable the user to observe the electromyographic signals that are produced when muscles contract, while maintaining the electrical isolation of the subject from any measuring or recording equipment that is attached to the system.

All MA300 EMG systems consist of two units (a backpack and desktop unit) with a single thin (2.66 mm diameter) coaxial connecting cable. The subject carries the backpack, attached to a belt or vest, with EMG pre-amplifiers and up to eight event switches. The EMG, event switch and other signals are digitized and processed within the backpack and transmitted as digital information to the desktop unit over the coaxial cable. This is a single core, ultra-light cable, 18 to 35 metres long that weighs less than 160 grams and does not encumber the subject in any way. The standard MA300 system does not use radio or infrared telemetry and can be used in almost any environment without any of the restrictions of wireless telemetry systems.



The MA300 system meets FCC Class B requirements and can normally be operated near magnetic, electrostatic, and radio-frequency fields without problems.

The MA300 is a small, lightweight and versatile system that avoids the problems of radio frequency interference inherent in traditional EMG radio telemetry systems. The ultra-light cable used does not restrict the subject in any way, unlike the cumbersome, multi-core cables required to transmit data in the traditional cabled EMG systems where a separate cable is used for each channel of information. By digitizing all signals at the subject, the MA300 guarantees a clean signal without any degradation from the transmission of analog signals.

Motion Lab Systems offers a range of features in the backpacks making them suitable for any gait or biomechanics application.

The backpack receives isolated low-level DC power from the desktop interface unit over the same cable that carries the EMG signal. This keeps the backpack unit lightweight, makes the system simple and reliable to use, and eliminates the need and expense of batteries. Since the system does not use radio frequencies there is no risk of interference or interaction with other equipment. Sophisticated electronic circuits within both units enable the reliable supply of power to the subject backpack while simultaneously transmitting digital information over the same cable. In addition, electrical isolation of the subject is maintained at all times.

The **backpack** is attached to a belt or vest worn by the subject and supports a number of EMG pre-amplifier channels. Our range of backpacks extends from basic units with only the essential features to units that include additional features such as a user controlled anti-alias filter, eight dedicated channels for event switches and four dedicated, low frequency, auxiliary channels for use with goniometers, accelerometers, strain gauges etc.

All backpacks feature an adjustable gain switch for each EMG channel that can be preset to any one of ten different values. This guarantees that your MA300 EMG System has a precise gain setting at all times while allowing the user complete control of the output signal levels. Each EMG channel includes an individual blue LED next to the gain control switch that lights when the signal level is close to an overload condition to warn the user if the gain control is set too high. In addition, all backpacks also include a recessed test button at the bottom of the backpack that allows the user to test each of the EMG channels by applying a 78Hz sine wave signal to all of the EMG channels – this can be used to automatically calculate the individual channel gain settings when using the Motion Lab Systems EMG Graphing or EMG Analysis software applications.



Some backpack models contain additional features such as an extended frequency response and an adjustable anti-alias filter that can preset the maximum EMG frequency that will be processed to avoid the possibility of recording signal aliasing errors. The ability to control the EMG bandwidth allows the user to specify the precise EMG bandwidth that they will work with and can easy EMG data collection in many cases. Backpacks without an anti-alias filter switch have a fixed DC-1000Hz -3dB bandwidth.

Unlike other EMG systems designed for biofeedback, animal, or research use, all MA300 systems meet the requirements for use in the United States on human subjects in a clinical environment.

A single green power light on the front of the backpack indicates that the unit is receiving DC power from the desktop unit, while individual blue lights next to each of the EMG channel gain controls alert the user to any potential signal overload on the individual EMG channels. The coaxial connector to the desktop interface cable is on the left side of the bottom of the unit while a green indifferent (or ground reference) connector is located on the bottom right side. This is a standard “TouchProof” DIN 42-802 connector that can be used to connect a ground reference electrode to the system that meets the performance standard for Electrode Lead Wires and Patient Cables, in Title 21 Code of Federal Regulations (CFR), part 898.

The **desktop interface unit** contains the isolated electrical interface to the subject unit. It supplies isolated, low-level, DC power to the backpack unit and converts the digitized EMG signals to analog signals suitable for connection to any data collection system. Front panel status lights show the DC power status and provide fault detection (No Signal) plus an indication of signal quality (the CRC light). Activity indicators for the eight dedicated event switch channels provide easy

individual switch monitoring and testing when using a backpack that supports dedicated event switch channels. These indicators do not indicate the status of event switches used in the EMG and Auxiliary channels. All MA300 backpacks support the use of event switches connected to the auxiliary or EMG data channels but only the dedicated event switch channels are displayed on desktop interface unit front panel.

Many Motion Capture systems and software analysis packages can automatically determine gait events and if you are using one of these systems with your MA300 then you may not need the event switches. Many data capture systems also provide facilities to directly monitor the EMG and other analog signals.

Your MA300 system will produce high quality raw EMG signals under clinical conditions without requiring any complicated set up or training period - if you can find the muscle, then the MA300 will provide the signal. The system has been designed to be reliable and easy to use under all circumstances and is supplied with EMG pre-amplifiers and all the cables needed to connect to any motion capture system or ADC system to start recording EMG and event data.

The easy upgrade path for all of the MA300 systems ensures that an EMG system can be purchased by any user with the confidence that additional capabilities can be added as the needs change.

Analog signal connection and installation information can be found at the end of this manual. Please contact technical support at Motion Lab Systems if you have any questions concerning the installation or signals provided by your MA300 system.



Specifications

The MA300 system is available in a range of different configurations to match the needs of a wide range of users. MA300 systems meet all basic gait lab requirements as well as those of advanced research users:

- ▶ **MA300-XII** has 12 data channels – this system has a fixed 1000Hz bandwidth and includes eight EMG channels and four auxiliary channels that can be used with event switches.
- ▶ **MA300-XVI** has 16 data channels – this system has a fixed 1000Hz bandwidth that features sixteen EMG channels but does not include any auxiliary or event channels.
- ▶ **MA300-18** has 18 data channels – this system has an adjustable low pass filter, six EMG channels, eight event switches and four auxiliary channels.

- ▶ **MA300-22** has 22 data channels – this system has an adjustable low pass filter, ten EMG channels, eight event switches and four auxiliary channels.
- ▶ **MA300-28** has 28 data channels – this system has an adjustable low pass filter, sixteen EMG channels, eight event switches and four auxiliary channels.

All MA300 systems consist of a Subject Back-Pack Unit (BPU), a Desk-Top Unit (DTU) and interconnecting coaxial cable with various accessories such as the EMG pre-amplifiers and event switches. This specification covers the two main electronic packages: the Back-Pack Unit (BPU) and the Desk-Top Unit (DTU). Electrical parameters are defined between the input connectors of the BPU and the 25 pin signal connector on the rear of the DTU.

MA300 systems are available with two different input connector types for the EMG and auxiliary channels – these can be either 4-pin BINDER or LEMO connectors.

All MA300 systems supporting dedicated event channels use the same connector type for the event channels, a 5-pin LEMO connector. If you are using event switches connected to the auxiliary channels or via any of the EMG channels then the event switch connector will normally be a 4-pin BINDER connector.

All of the EMG channels in MA300 systems have identical signal processing facilities with the exact frequency range depending on the model. MA300 systems without a variable anti-alias filter have a fixed DC-1000Hz bandwidth while our high-end systems can set the upper bandwidth via a user controlled filter.



Systems featuring dedicated events channels have two event switch input connectors, each with four binary switch inputs. The dedicated event switch specifications apply to each of the eight total binary input channels that are available as a pair of encoded analog channels at the MA300 output connector. In addition, many MA300 systems also include four auxiliary channel inputs that accept low data rate signals with a bandwidth of DC to 120Hz.

All MA300 systems can accommodate an optional internal band-pass filter assembly in the DTU that provides a variable high-pass filtering as well as a pre-set low-pass filter for each EMG channel. These can be set to ensure that the EMG signals produced by the MA300 do not exceed the capabilities of the user's external analog system data collection system. This optional filter is fitted in the DTU in addition to the built-in low-pass filter in the MA300 backpack. Full details of the optional band-pass filter can be found at the end of this manual - the quoted specifications for the MA300 system assume that the optional band-pass filter has not been fitted.

All MA300 systems share a common feature set, design and construction methods that ensure that all our systems share a common performance baseline within the design limits of the specified features of each system.

Motion Lab Systems reserves the right to alter or amend specifications without notice.

Performance Conditions

The following electrical specifications are valid for the MA300 electronic units after a 15-minute warm-up, an ambient temperature of 20°C to 30°C and 40 to 60% relative humidity (non-condensing).

All MA300 systems are tested to meet performance and electrical safety specifications before shipment.

These specifications apply to all MA300 systems unless otherwise noted.

MA300 Characteristics

The characteristics of the MA300 are grouped into EMG, Auxiliary (Low Speed) channels, Event Switch, Power Line, Environmental, and Physical. Unless otherwise noted, it is assumed that the system is a cabled MA300 system set up for the default conditions with a DC to 2000 Hz system bandwidth and preamplifiers that include a 10Hz high pass filter. It is further assumed that the EMG mid-band test frequency is a 200 Hz sine wave.

System Specifications

Number of EMG channels	6, 8, 10 or 16 depending on model selected.
Dedicated event channels	8 binary (on/off) event channels (if fitted).
Number of Auxiliary channels	4 channels, DC to 120Hz (if fitted).
EMG signal output level	±5 Volts Full Scale.
Variable Low Pass Filter	10 pole Bessel, -3dB at 350, 500, 750, 1000, 1250, 1500, 1750 and 2000 Hz.
Fixed Low Pass Filter	10 pole Bessel, -3dB fixed at 1000 Hz.
Group Delay (input to output)	< 2ms @ 1kHz (cabled and telemetry systems)
Electrical Isolation	1500 V DC Applied part
EMG pre-amplifier input noise	Less than 2 µV RMS nominal, C.M.R.R. >100 dB at 40 Hz.
AC input rating	100-240 Volts, 50VA, 50/60 Hz

All MA300 signal outputs are electrostatic discharge protected, in addition, all Motion Lab Systems EMG pre-amplifiers supplied with the MA300 are ESD and RFI protected.

Event channels and the Variable Low Pass Filter are features of the high-end MA300 systems. Some MA300 systems do not have dedicated event channels and have a fixed EMG signal bandwidth. Auxiliary channels are not available on the MA300-XVI system.

Subject Back-Pack Characteristics

EMG Inputs

Input Impedance	31 KΩ	At the backpack input connectors.
Input max Level	500 mV	Peak to Peak

Backpack Bandwidth	DC – 2,000 Hz*	-3 dB at 2kHz.
Internal sample Rate	5,000 samples / sec.	Per individual EMG channel.
Unit Gain Range	10 to 500	(± 5%) ten (10) switch settings.
Signal to Noise Ratio	>50 dB	(At full scale output)
Crosstalk	>50 dB	Adjacent EMG channels

* MA300-XII and XVI backpacks are limited to 1kHz.

All second generation MA300 backpacks generate an internal test signal that is a 78Hz sine wave of 8.8mV peak to peak applied to the backpack inputs. This is equivalent to a peak to peak signal level of 440uV at the input of a standard (x20 gain) preamplifier.

Low Speed auxiliary Inputs (where available)

Input Impedance	31 KΩ	At the backpack input connectors.
Input max Level	2.5 Volt	Peak to Peak
Signal to Noise Ratio	>40 dB	(At full scale output)
Crosstalk	>40 dB	Inter channel crosstalk.
DC Power available	5 Volts at 10 mA	Isolated DC power.

Desk-Top Unit Characteristics

EMG Outputs

Output Impedance	100 ohms, 10%	±5 Volts max at 10 mA.
Desk Top Unit Gain	2 (± 5%)	±5 Volts full scale output.
Over Voltage Protection	±5.2 Volts	Zener clamped.

EMG Subject Isolated Interface

Hi Pot Test	1500 V DC	for 10 seconds (<1 mA)
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EMG Pre-amplifier Characteristics

The surface EMG pre-amplifiers supplied with the may use pre-gelled snap Ag/AgCl electrodes, surface-mounted disks, or fine wires with a suitable adaptor.

All preamplifiers feature a built-in instrumentation amplifier using a dual differential front-end, full static (ESD) protection, muscle stimulator protection, and include a Radio Frequency Interference (RFI) filter.

Input Impedance	> 100,000 MΩ.
Input Configuration	Dual Differential front-end
Input Protection	> ± 40V DC
Equivalent Input Noise	< 2μV RMS nominal.
C.M.R.R.	> 100 dB min at 40 Hz.
Bandwidth (-3 dB)	10Hz to 3.5kHz (MA420), 20Hz to 3.5kHz (MA411/416)

Pre-amplifier Gain	20 ($\pm$ 2%).
Body size	38 mm x 19 mm x 9 mm.
Weight	20 grams.
Connector	4-pin BINDER or LEMO connector

Dedicated Event Inputs (if fitted)

Input Impedance	10 K Ω 3% Pulled to 5 Volt DC
Logic Threshold	2 to 3 Volts DC
Delay (ON or OFF)	< 1.5 msec
Pressure to "close"	Less than 150 gm
Analog Outputs	0 to 4.688 Volts Full Scale
Analog Impedance	100 ohms 5 mA maximum
Analog Encoding	Weighted binary 1, 2, 4, 8
Analog Accuracy	0.6% of Full Scale 10 mV DC absolute.
Connector	5-pin LEMO.

AC Power Supply Characteristics

Connector	3 pin IEC 622 style
Line Volts	Auto selected - working range 100 - 240 Volts AC.
Line Frequency	50/60 Hz.
User Replaceable Fuses	Dual 500 milliamp, slo-blow 20 mm fuses.
Wattage	40 VA
Safety Compliance	The AC power supply (Condor GSM28-12) is certified to be in compliance with the applicable requirements of UL-2601-1 First Edition, CSA 22.2 No. 601.1 and IEC601-1 1988 Amend. 2. The unit is in conformity with the applicable requirements of EN60950 following the provisions of the Low Voltage Directive 73/23/EEC.

Environmental Characteristics

Operating Temperature	20°C to 40°C
Storage Temperature	-15°C to 55°C
Relative Humidity	Maximum 90%, no condensation.
Shock (two hits)	30 G max each axis

Physical Characteristics

Subject Unit dimensions	135 x 105 x 42 mm. 5.2 x 4.2 x 1.6 inch (DxWxH)
Subject Unit Weight	0.4 Kg (14 Ounces)

Interface Unit dimensions	318 x 75 x 290 mm. 12.5 x 3.0 x 11.5 inch (DxWxH)
Interface Unit Weight	4.3 Kg (9.5 lb.)

The desk top unit enclosure is made from injection molded glass-reinforced polycarbonate and is rated V-O in the UL flammability test.

Group Delay

The delay from an EMG signal at an MA300 preamplifier to the analog output of the MA300 system is called the Group Delay and constant across all EMG channels. Due to the unique design of the MA300 system the group delay remains constant for both the traditional cabled MA300 systems and MA300 systems that use the radio telemetry option. Switching between cabled data transmission and radio telemetry data transmission does not affect the group delay.

The group delay that an EMG system adds to the EMG signals is an important factor whenever EMG data is sampled and analyzed in combination with motion or force data. This is because large delays (greater than the motion or force sampling rates) in the EMG data will cause a loss of synchronization between the EMG signal and the motion or force data. All MA300 systems have a group delay less then 2ms (EMG bandwidth >1kHz) thus typical 3D systems that sample data at 60 or 120 frames (samples) per second will remain perfectly synchronized with EMG data from any MA300 system.

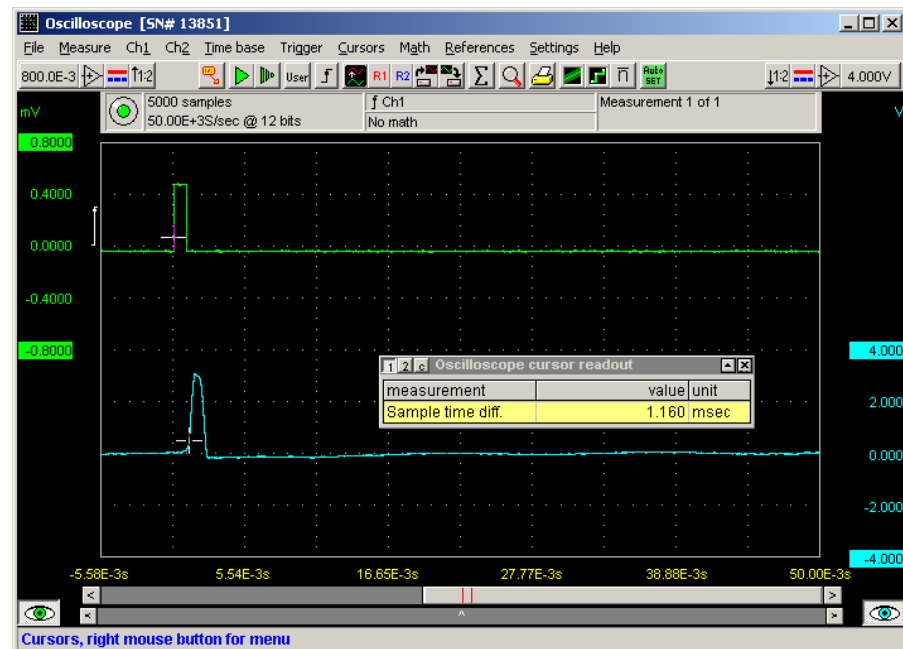


Figure 1- 1ms pulse applied to the preamplifier input (green) with MA300 output (blue).

The only factor that affects the total group delay from signal input to signal output is the high frequency bandwidth of the MA300 backpack – MA300-XII and MA300-XVI systems have a fixed bandwidth with an associated group delay of less then 2ms across all EMG channels.

MA300-18, -22, and -28 systems with the built-in low-pass filter will have a group delay that is proportional to the low-pass filter settings – this can range from 1.2ms at 2kHz bandwidth to 4.4ms at the lowest 350Hz filter setting. In all cases this delay is less than the sample resolution of a 3D motion capture system running at 120Hz

frame rate (8.3ms) so EMG data recorded in combination with 3D motion data is always perfectly synchronized when using MA300 EMG systems.

The group delay of the MA300 system remains unchanged when the MA300-RT radio-telemetry option is used. However, using the diversity receiver option will add an additional 250ns to the overall system group delay. This is insignificant when compared to the typical Group Delays of competing radio-telemetry EMG systems which can introduce EMG signal delays of 15-50ms as shown in the illustration below when testing a well known competing commercial telemetry EMG system under identical conditions to the MA300 Group Delay test.

Almost all commercial EMG radio telemetry systems have larger Group Delays than the minimal delay of an MA300 EMG system.

This illustrated 15.6ms delay between the EMG signal detection at the skin surface, and the signal appearing at the analog output, is equivalent to a delay of 2 frames of 3D data at 120Hz (8ms per frame). This means that, when EMG data is recorded with one of these systems in a gait environment, the 3D marker position data and force plate data will be recorded in real-time but the EMG data will lag the real-time data by 2 frames with this competing system. Many commercial wireless telemetry systems have even longer delays resulting in substantial synchronization problems.

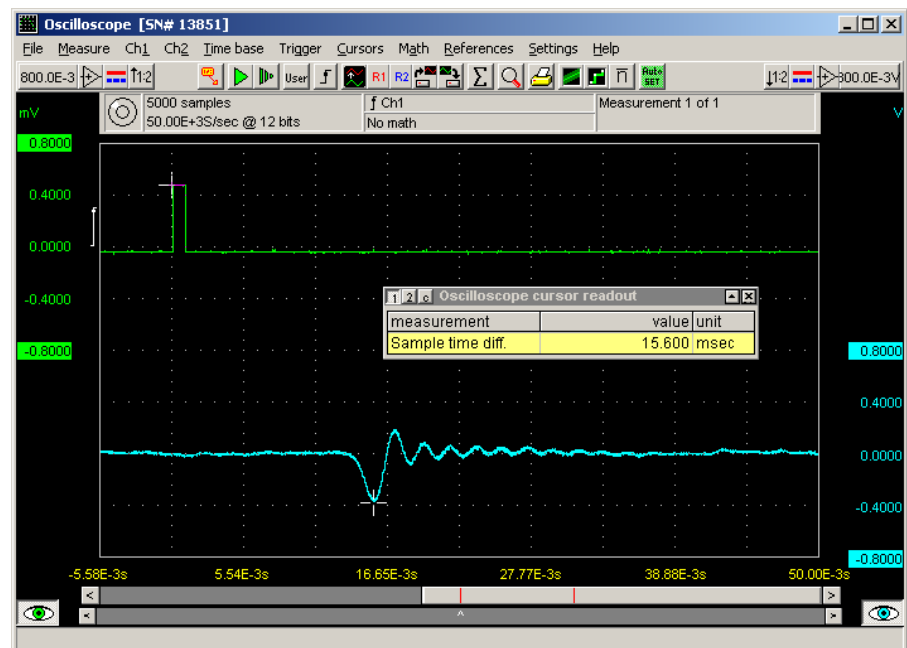


Figure 2 - A typical Group Delay generated by a competing telemetry EMG system.

The corresponding Group Delay introduced by an MA300-28 system is only 1.1ms at full 2kHz bandwidth, offering real-time performance and making video and 3D motion capture data synchronization error free. In addition to a minimal delay, the full EMG bandwidth of the MA300 systems results in a much cleaner and more accurate EMG signal than competing, lower bandwidth systems with low quality filters that distort the EMG signals.

System Connections

All MA300 systems consist of two units, a desk-top interface unit and subject backpack with its associated EMG pre-amplifiers and event switches. In use, the subject backpack is attached to a belt or vest on the subject via a Velcro® pad on the rear of the belt. The interface and the backpack are connected via a thin, lightweight cable with a locking coaxial connector at both ends that powers the subject unit and carries the EMG signals back to the interface unit. A radio telemetry option is

available that replaces the cable with a radio-transmitter / rechargeable battery pack on the subject and a matched radio receiver connected to the desk top unit via the standard MA300 coaxial cable. The cable and radio telemetry options are interchangeable allowing the user to switch from one connection method to another in seconds.

The connection to the backpack is at the bottom of the unit so that the cable can trail behind the subject, allowing them a large amount of freedom to walk or otherwise move around the testing area. The connection between the backpack and the computer interface uses a lightweight, single core, coaxial cable that plugs into the bottom of the backpack and couples to the desktop interface via a connector at the top of the back of the desk-top interface unit.

The backpack can be connected or disconnected from the interface unit at any time - subject safety is assured by electrical isolation of the backpack from the desk-top interface (see specifications for details). Please note that it is not necessary to turn the desktop interface unit off before connecting or disconnecting the backpack.

The desktop interface unit can be powered by any common AC line voltage in the range of 100 Volts AC through to 240 Volts AC. When AC power is applied to the unit, it will automatically detect the AC power voltage and configure itself for the correct range. There are no settings to worry about - this auto-configuration will occur each time the MA300 system is connected to the AC power. As a result it is not necessary open the interface unit to select the correct power voltage.

Electrical Safety

All MA300 systems are UL marked and tested to meet UL 2601-1 - UL Standard for Safety Medical Electrical equipment.

Each MA300 system is tested before it leaves the factory to ensure that the backpack interface provides the specified DC electrical isolation. The system meets all U.S.A., electrical safety standards for patient connected equipment, including leakage and is tested to meet UL 2601-1 - UL Standard for Safety Medical Electrical equipment, Part 1: General Requirements for Safety Second Edition. The maximum voltage supplied to the backpack, carried by the subject, is 9 volts DC via the isolated interface. All power supplied to the EMG pre-amplifiers and event switches is current limited. The system power supply is a U.L. and C.S.A. approved power supply with CE marking and uses U.L. approved wiring and components for all internal power supply connections.

It is not necessary to switch the MA300 desk top unit off when connecting or disconnecting the subject backpack. All signal output lines are protected against electrostatic discharge and radio frequency interference. The MA300 system is tested to meet the FCC radio frequency emission regulations, Part 15 Subpart J, Class B - suitable for Home or Office use. For complete information please refer to the section on *International Standards Compliance* at the beginning of this manual.

Maintenance

Under normal use the MA300 system does not require any internal adjustments. The cover should only be removed by qualified personnel to ensure that the electrical isolation and radio frequency shielding is maintained. There are no user-serviceable components inside MA300 systems. All day-to-day set-up functions can be performed without disassembling either the backpack unit or desktop interface unit.

Cleaning

This may be performed as necessary. After disconnecting the MA300 from the AC power cord, you may clean the exterior of the MA300 with a damp cloth using a

mixture of soap and water or isopropyl alcohol swabs. Wipe the system dry before connecting the AC power cord. Do not immerse in water or any other cleaning solution.

Preventative Maintenance

The MA300 system does not require any routine preventative maintenance to ensure its performance. System performance may be checked using a Whisper EMG Test Set and Simulator or similar biomedical simulator.

Preventative Inspection

Routine preventative inspection maintenance may be performed once a week or as necessary depending on system usage. All EMG pre-amplifiers should be connected to the backpack and tested. A simple test can be performed by applying each EMG pre-amplifier to the surface of a muscle and observing a muscle contraction. The coaxial cable connecting the subject backpack to the desktop unit should be checked for any cuts or other damage and replaced if necessary.

System Performance

Users may choose to perform a complete system specification test on the MA300 system at intervals appropriate for their environment. System specification tests may be performed using biomedical signal generators such as the Whisper EMG Test Set and Simulator (Roessingh Research and Development), the Model 220 Biomedical Function Generator (Medi Cal Instruments), or any similar equipment setup.

Note that tests of many parameters, such as Common Mode Rejection Ratio, may require very precise experimental conditions due to the very low signal levels normally encountered with biomedical signals. In addition, most common test signal sources have single ended outputs that are unsuitable for application to the differential inputs of the MA300 preamplifiers. Even very small amounts of external interference from AC line sources can produce erroneous results in many situations.

Setting up the MA300 system

Getting started

You must set your analog recording sample rate to at least twice the highest frequency in the EMG signal. This is a minimum requirement – if possible sample the signal at 3-4 times higher.

The instructions in this manual apply to all MA300 systems using LEMO or BINDER connectors regardless of the number of EMG, auxiliary, or event channels in your system.

Before you use the MA300 system to collect data, you must check that the backpack unit (BPU) EMG bandwidth will provide the EMG signals that you need for your experiment. The required signal bandwidth will be determined by the system that you are using to record the EMG data and on your experimental protocol. If you are using an MA300-XII or MA300-XVI system then your maximum signal bandwidth is fixed at 1000Hz. The MA300-18, 22 and 28 systems (shown below) include a variable anti-alias filter (low pass filter) that is controlled by a small rotary switch at the lower left side of the backpack unit and will need adjustment if you change your analog sampling rate.

It is vital that your analog recording system samples the data from your MA300 system at an adequate rate as the failure to sample EMG data fast enough is one of the major causes of EMG signal corruption. MA300 systems that include an anti-alias bandwidth switch provide considerable flexibility in the choice of EMG bandwidth while the fixed bandwidth of other MA300 systems will meet the needs of many users.

The EMG bandwidth at the skin surface is generally less than 500Hz; however fine-wire EMG recordings may easily contain signal frequencies up to, and beyond, 1000Hz. If in doubt, we recommend that your analog sampling rate is higher than 2000 samples per second (2kHz) with a bandwidth of 1000Hz (1kHz) for high quality EMG recordings under most circumstances.

In addition to selecting the correct EMG sample rate for your EMG data (as determined by your EMG recording system anti-alias, or low pass, filter), if you have purchased the optional MA300 high-pass filter, you can also set the high pass filter frequency via a rotary switch on the back of the desktop interface unit. Setting the high-pass filter can improve your EMG signal by removing low frequency motion artifact signals but this feature is not critical for EMG signal fidelity.



Individual EMG channel gains may be set at any time during system operation and the system gain will immediately change to reflect the new selection. You may wish to record any gain selection changes for use in subsequent data analysis.

Default system configuration

Without the optional high pass filter the MA300 supplies raw EMG signals, each with a bandwidth that goes up to 2,000 Hz (-3 dB) for systems with an anti-alias bandwidth switch and 1,000 Hz (-3dB) for the basic MA300 systems. The EMG signal output levels are fixed at a maximum of ± 5 volts. Actual output voltages will depend on the level of the EMG input levels and the setting of the individual EMG channel gains.

Analog event signals are a feature of the some MA300 EMG systems.

The two dedicated analog event switch outputs available on some MA300 systems will, by default, produce a signal between 0 and +4.688 Volts. This signal will have up to sixteen different levels depending on the combination of each of the four input switches closed at any instant.

If you are connecting your event switches to an EMG data channel then the event switch signals will appear on that data channel as a simple +ve DC voltage level. Event switch signals from EMG data channels may need additional preprocessing compared to the signals from the dedicated event channels.

Raw EMG output

Your MA300 system can supply from six to sixteen channels of raw EMG signals depending on the model that you have purchased. The bandwidth of these signals may be modified by the action of the built-in low pass filter and optional high pass filters described later.

The raw EMG signal is the normal, unprocessed electrical signal seen directly from the muscle during a contraction. Raw EMG signals can have a high bandwidth and in certain circumstances frequency components over 1,000 Hz may be recorded. Some data recording or analysis systems cannot respond to frequencies this high and will produce an “alias” artifact signal when high frequency EMG signals are seen by the data recording system. MA300 systems without an adjustable bandwidth filter will always filter and attenuate all signals that are greater than 1000Hz.

If you have an MA300 system with an anti-alias bandwidth switch you may wish to filter the higher frequency EMG signals so that you do not attempt to record higher frequency signals than your recording equipment can handle. MA300 systems with an anti-alias bandwidth control can use one of the low pass filter settings of 350 Hz, 500 Hz, 750 Hz, 1000 Hz, 1250 Hz, 1500 Hz, or 2000 Hz to reduce the signal bandwidth to a more manageable range so that the MA300 system does not present the recording system with any signal components above the Nyquist point.

Your analog recording system should be set to sample data at least twice as fast as the highest frequency that the MA300 can produce. If you are using an MA300 system with a fixed, 1000Hz bandwidth, then you must sample your EMG data at 2000 samples per second or faster.

Systems with the anti-alias bandwidth switch have greater flexibility in setting the analog EMG signal sample rate. Good quality surface EMG can be obtained with the backpack filter switch set to 7 - resulting in an EMG bandwidth up 350 Hz and consequently an EMG data sample rate of 700 samples per second or faster.

Always chose a high sample rate if there is any doubt about the correct sample rate for your EMG data. Higher sample rates produce larger EMG data files but these file will always contain more accurate data then files created at lower sample rates.

In addition, over-sampled data can always be re-processed after the recording session to produce smaller files with lower sample rates. It is impossible to recover EMG data after the recording session if the analog sample rate was too low to accurately represent the EMG information and frequency content of the incoming signals.

Calibration and EMG output levels

The MA300 EMG system has a wide dynamic range with individual gain controls provided for each EMG channel using one ten position rotary switch per EMG channel. Therefore, the effective system gain is always fixed to discrete value and the EMG output of the MA300 system is always calibrated so long as the individual channel gain selections are known. As a result, the EMG output levels from the MA300 can be directly related to the detected EMG level at the pre-amplifier inputs.

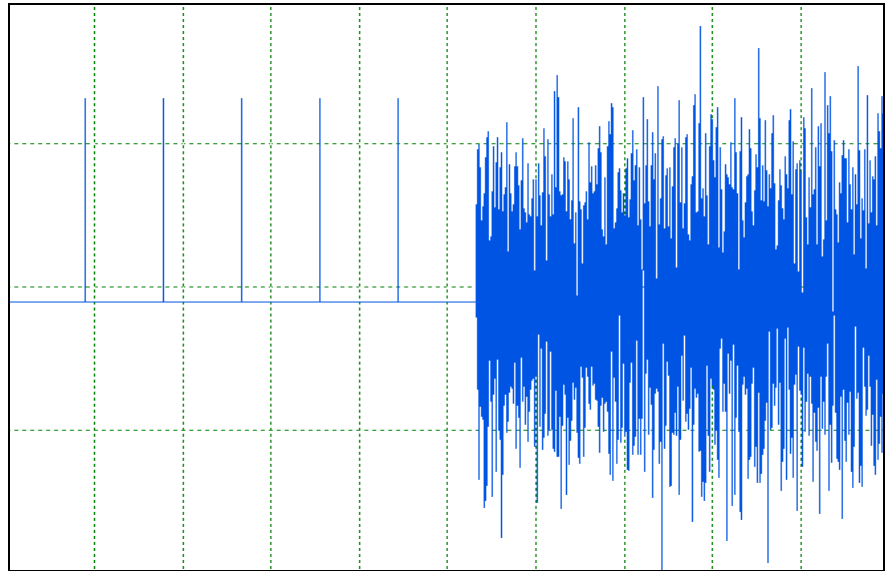


Figure 3 - Five calibration pulse precede the start of the calibrated Whisper EMG signal

When used with the standard x20 gain preamplifiers, the gain figures shown below are accurate within 5% of the stated value for the system bandwidth as determined by the internal low pass filter and the optional band pass filter.

MA300 gains when using the standard x20 preamplifiers

Back Pack Gain Switch	System Gain	Maximum Input Level
0	350	±18.0 mV
1	2000	±6.0 mV
2	4000	±2.8 mV
3	5700	±2.0 mV
4	8000	±1.4 mV
5	9500	±1.2 mV
6	11500	±1.0 mV
7	13200	±0.9 mV
8	16600	±0.7 mV
9	18000	±0.6 mV

Switch settings 2 through 5 are appropriate for most EMG signals when using the standard range of x20 gain preamplifiers.

The system gain figures shown above include the EMG pre-amplifier gain - normally 20 if using an MA-411. Thus with Back Pack Gain Switch setting 2 (gain of 4,000), the EMG channels, when connected to an MLS EMG pre-amplifier, accept any signal with a bandwidth of 20 to 2,000 Hz that has an input range of ± 2.8 millivolts or 5.6mV peak to peak. This produces a full-scale output of ± 5.00 volts (10 volts peak to peak) with an effective resolution of 1.4 $\mu\text{V/bit}$ at the EMG pre-amplifier signal inputs ($5.6\text{mV} / 2^{12}$).

These overall gain values will change if the preamplifier gain is not x20 – users may optionally use our high gain Z03 or Y03 range if high gain is required. These higher gain preamplifiers (x300 gain) may be used interchangeably with the standard x20 range of preamplifiers if necessary and will increase the overall gain of each individual channel using a high gain preamplifier by a factor of 15 over the standard x20 preamplifier.

MA300 gains when using high gain preamplifiers (x300)

Back Pack Gain Switch	System Gain	Maximum Input Level
0	5250	± 1.2 mV
1	30000	± 0.4 mV
2	60000	± 0.19 mV
3	85500	± 0.13 mV
4	120000	± 0.10 mV
5	142500	± 0.18 mV
6	172500	± 0.07 mV
7	198000	± 0.06 mV
8	249000	± 0.05 mV
9	270000	± 0.04 mV

Exact gain measurements may be made using a known biomedical calibration source or by using the built in test signal reference and factoring in the preamplifiers gain (x20 or x300) into the gain calculations as the test reference signal is applied to the backpack inputs, not the preamplifier inputs. Thus the test reference signal level is independent of the preamplifier gain used by individual channels and only reports the individual backpack channel gain settings.

The MA300 system gain on each of the four auxiliary research channels is x2. The auxiliary channels accept any analog signal with a bandwidth of DC to 120 Hz and a range of ± 2.5 volts. This will produce a full-scale output of ± 5 volts with a minimum resolution of 2.44 mV at the desktop output for each auxiliary channel (indicated on the output cable as Low A through Low D signals).

The auxiliary connector is not available on the basic MA300-XVI system. Event switches and other devices may be connected to this system via the EMG data channels.

A small amount of isolated DC power is available for interface purposes at the auxiliary connectors. This power is drawn directly from the backpack power supply and care must be taken to avoid excessive current drain when constructing any external interface circuitry. Any external circuitry using this isolated DC power should provide its own regulation and AC decoupling. Care must be taken to avoid RF radiation and EMI pickup with any external circuitry connected to the MA300. Please contact technical support at Motion Lab Systems if you are in any doubt about connecting external interface circuitry to your MA300 system.

Working with C3D files

EMG data in C3D files is often created when an EMG system is connected to an Analog to Digital Convertor (ADC) controlled by a 3D motion capture system or other data recording system like the Dataq WINDAQ.

Many MA300 systems are used with motion capture systems that use C3D files to store the recorded EMG information together with force data and 3D trajectory information. The analog data within C3D files can be calibrated by storing an analog scale parameter for each analog channel. This scale factor is usually calculated to report either the data in terms of “volts applied to the ADC inputs” or, the data values actually measured by the device. The scale factors that are discussed in this section are simply numbers that are used in the mathematical formulas shown here to allow you to convert the recorded EMG data into some form that can be easily discussed and analyzed. Most people find it much easier to think of the actual EMG signal in terms of *micro-volts at skin surface* (or *percentage MVC*) rather than the more technical *digital sample values* or *Volts* produced by an EMG system.

The following discussion assumes that the reader is familiar with C3D files, a public file format used by most 3D motion capture systems and in common use in biomechanics laboratories worldwide. This section attempts a brief overview – a far more detailed discussion of the factors affecting C3D scale factors and a full explanation of the calculation of these scales can be found on the C3D web site at <http://www.c3d.org>.

Default C3D scale factors

It is recommended that all EMG signals in a C3D file are scaled in terms of “Volts applied to the ADC inputs” – normally this will have a range of ± 5 Volts.

The magnitude of the recorded EMG signal is affected by the ADC hardware as well as the individual EMG channel gain switch settings. Since the user can change the individual gain settings for each channel, it is normal to select C3D scale factors that simply scale the MA300 system output in terms of volts produced by the MA300 system and allow another application to scale the results to take into account the individual EMG channel gains. This is the recommended C3D scaling method and is required if the data is to be processed using either the **EMG Analysis** or **EMG Graphing** applications available from Motion Lab Systems.

Assuming an ANALOG:GEN_SCALE factor of 1.00 and an output signal range of ± 5 from the MA300, the ANALOG:SCALE factors for each EMG channel are:

12-bit ADC ANALOG:SCALE = 0.002441406

16-bit ADC ANALOG:SCALE = 0.000152588

These values will produce a C3D file with all EMG data scaled to ± 5 Volts – this is the recommended method of scaling EMG data and is required if the EMG data is to be analyzed using any Motion Lab Systems software application. These applications contain functions that provide methods of scaling the reported data with respect to the individual EMG channel gains.

If you scale the EMG channels in volts using either of the above parameter values, we recommend that you modify the ANALOG:UNITS parameter to “V” to indicate correct scaling values.

Complete information on the C3D file format, with worked details of analog scale calculations, and a full manual, is available on the Internet at <http://www.c3d.org>.

Individual C3D scale factors

Motion Lab Systems DOES NOT recommend the use of individual scale factors for EMG data analysis.

Alternative, the EMG data can be recorded and viewed with the data calibrated in microvolts (μV) at the skin surface by entering individual scale factors for each analog channel. The value of these individual channel scale factors (called ANALOG:SCALE parameters) can usually be determined from your data

collection system documentation or calculated from the following formula:

$$SCALE = \frac{BIT/GEN\_SCALE}{GAIN}$$

The GEN_SCALE value is normally chosen when the analog data collection (ADC) system is installed. The value of GEN_SCALE is normally preset and affects all ANALOG:SCALE calculations - it should not be changed without careful consideration of the effects on any other analog signals recorded in the C3D file. The BIT value represents the value of 1-bit in Volts and is determined by the characteristics of the ADC collection system. It can be calculated from the following formula:

$$BIT = \frac{range/gain}{resolution}$$

where *range* is the ADC input range in Volts, *gain* is any ADC gain factor that is applied to the channel, and *resolution* is the bit resolution of the ADC (i.e. 4096 for a 12-bit ADC or 65536 for a 16-bit ADC). Note that the range value is the full ADC measurement range - this will have a value of 20 for most common ± 10 -volt ADC systems. When calculating the *gain* used in this equation you must take into account the amplification applied to the EMG signal at every stage in the EMG recording and data collection process – preamplifier, the EMG system, and ADC. It is strongly recommended that the calculated gain is verified by direct measurement.

An Excel spreadsheet that calculates all analog C3D scale factors is available from Motion Lab Systems.

A table of ANALOG:SCALE parameters is given here to scale the C3D file output in microvolts at skin surface for GEN_SCALE values of both 0.0048828 and 1.000. Both these ANALOG:GEN_SCALE values are commonly used with 12-bit ADC data collection systems that sample data with a ± 10 Volt range.

Note that setting the GEN_SCALE value to 1.00 will result in very small individual ANALOG:SCALE values that are very small if the users attempts to scale the output results in terms of microvolts at skin surface. Some software applications may have problems with interpreting very small ANALOG:SCALE values. The following values assume that the ADC range is ± 5 Volts (a ± 10 Volts ADC with a gain of x2), and the ADC resolution is 12-bits:

Gain Switch	ANALOG:SCALE value if GEN_SCALE is 1.000	ANALOG:SCALE value if GEN_SCALE is 0.0048828
0	0.0000070358	0.0014409259
1	0.0000012624	0.0002585322
2	0.0000006226	0.0001275188
3	0.0000004432	0.0000907773
4	0.0000003172	0.0000649690
5	0.0000002631	0.0000538911
6	0.0000002193	0.0000449157
7	0.0000001912	0.0000391482
8	0.0000001477	0.0000302591
9	0.0000001349	0.0000276183

If you enter the appropriate parameter value for the ANALOG:SCALE then we recommend that you also modify the ANALOG:UNITS parameter to “ μV ” to indicate the new scaling values. Complete information on the C3D file format is available on the Internet at <http://www.c3d.org>.

Selecting the EMG frequency bandwidth

The default maximum EMG signal bandwidth for MA300 systems with a variable anti-alias bandwidth switch is 2kHz, and 1kHz for the systems without the anti-alias switch.

If your EMG system does not have an anti-alias switch then you can skip this section. All MA300-XII and MA300-XVI systems have a fixed 1000Hz EMG bandwidth.

Sometimes the full bandwidth of the MA300 system will be higher than your data collection or data recording equipment requires, or it may just be higher than you require for a particular experimental protocol. If you have one of the MA300 models with an anti-alias bandwidth switch then you can select a lower EMG signal bandwidth by filtering the higher frequency components of the EMG signals – thus reducing the bandwidth of the raw EMG signal to a range that is suitable for your recording system (or experimental protocol) and is essential to eliminate the danger of signal aliasing (Nyquist sampling errors) that can corrupt the EMG signal.

The anti-alias bandwidth switch controls a high quality, Bessel, variable anti-alias filter that can be preset by the user to control the bandwidth of the data signals from the system. A Bessel filter is a variety of linear filter with a maximally flat group delay (linear phase response) with an almost constant group delay across the entire EMG signal bandwidth, thus preserving the wave shape of filtered EMG signals without introducing spurious signals that may affect the EMG frequency spectrum.

This filter allows the user to limit the higher frequency content of the EMG signal to ensure that the analog recording system is not presented with ‘out-of-band’ signals that could cause unwanted artifact in the recorded EMG signals when the analog sampling rate is not high enough. According to the Nyquist sampling theorem the analog sampling rate should be at least twice the maximum frequency component of the signal of interest – in this case the EMG signals. In other words, the maximum frequency of the EMG signal should be less than or equal to half of the ADC system sampling rate to avoid the introduction of aliasing artifact into the EMG signals that you wish to record.

The MA300 Anti-Alias Filter

All EMG signals from the backpack are low pass filtered before being transmitted to the desktop unit. This restricts the highest frequencies available from your MA300 to levels set by the low pass filter within the backpack. This anti-alias filter will pass all frequencies lower than the value selected and attenuate all analog signal components higher than the chosen value.

The variable anti-alias filter available on some MA300 systems provides seven different settings at 350, 500, 750, 1000, 1250, 1500, and 2000 Hz and is controlled by a rotary switch on the backpack unit.

The inclusion of high quality Bessel anti-alias filters for each EMG channel in the MA300 systems allows raw signals to be recorded at the full bandwidth of your analog recording system. As a result, it is important that the data collection system analog sample rate is set to a suitable frequency taking into account the bandwidth of all the signals.

It is essential to filter raw EMG signals before recording to ensure that your data does not contain any frequencies that your data collection system cannot record. Basically your ADC sample rate MUST be at least twice as fast as the upper signal bandwidth. For example, if you are sampling an EMG signal at 1200 samples per second then you should select the 500 Hz low pass filter. However, if your clinical



MA300-X systems without an adjustable anti-alias filter have a fixed 1000Hz - 3dB bandwidth.

protocol requires EMG signals up to 1000Hz (for instance if you are involved in fine-wire recording for research purposes) then you should select filter setting 4 (1000Hz) and sample the signal at a minimum of 2000 s/s to ensure adequate signal quality and avoid the possibility of aliasing artifacts.

Filter Switch	EMG Bandwidth	Minimum Sample Rate
0	2000 Hz.	4000 s/s
1	1750 Hz.	3500 s/s
2	1500 Hz.	3000 s/s
3	1250 Hz.	1500 s/s
4	1000 Hz.	2000 s/s
5	750 Hz.	1500 s/s
6	500 Hz.	1000 s/s
7	350 Hz.	700 s/s

If you are collecting EMG data for research or you intend to perform frequency spectrum analysis on the data then you should (whenever possible) set the MA300 system filter switch to “0” and sample the data at 4000 samples per second or higher for maximum accuracy. If your data collection system has a lower maximum sample rate then set the filter switch accordingly.

The overall EMG system bandwidth is set by the backpack anti-alias filter.

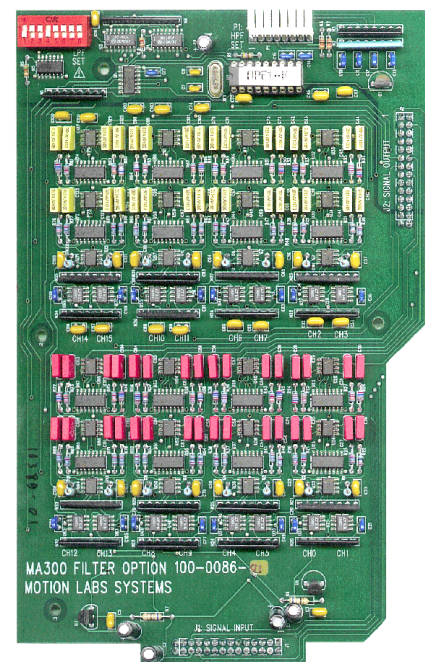
By filtering the EMG signal in this way, before the signal is sampled by your motion capture or data collection system, you will avoid the problem of “signal aliasing” that occurs when a signal changes faster than it can be recorded or analyzed. Signal aliasing can introduce false signals into the sampled EMG that interferes and distorts the original EMG signal. It is impossible to filter an EMG signal to remove aliasing artifact after the signal has been recorded so optimal filtering is essential.

The anti-alias filter is set whenever the switch setting is changed – this may introduce a momentary spike into each analog channel so is important that the anti-alias switch is only changed prior to recording EMG signals. Changing the anti-alias filter switch after starting to record an EMG trial is not recommended.

Band-Pass filter option

In addition to the built-in anti-alias filter, the MA300 offers an optional Band Pass Filter that allows the user to dynamically set the High Pass filter frequency (thus removing most typical motion artifact signals) and preset a Low Pass frequency to ensure that the MA300 never produces analog signals with a higher frequency content than your data collection system can sample or record.

The filter can be installed in the EMG signal path, inside the MA300 desktop unit, and is powered by the internal MA300 power supply to eliminate the possibility of introducing ground loops or external interference into the EMG signal. Although the installation is usually done at



If your system does not have a rotary switch at the top of the rear panel of the MA300 desktop unit then you do not have this option.

All MA300 systems can be upgraded to include the filter by purchasing the optional filter assembly.

The filter does not apply to the research channels that are available on the 16-channel system, nor does the filter apply to the event switch channels, which are processed separately.

the factory, prior to system sale, instructions are included at the end of this manual to allow users to add this useful feature to their system after the initial purchase.

The primary function of the optional filter is to restrict the low frequencies that the MA300 interface unit can output to your data collection or data measurement system. A high pass filter will, as its name suggests, pass all frequencies higher than a certain value. You may select this value to 20, 40, 60, 80, 100, or 120 Hz. — a common setting is 40 Hz for surface EMG recordings. The principal function of this filter is to reduce the amount of the low frequency artifact (or noise) component of the EMG signal. This tends to produce EMG signals with a flat baseline that may be easier to analyze in many gait protocols. The high pass filter frequency is set via a rotary switch at the rear of the Desk Top Unit.

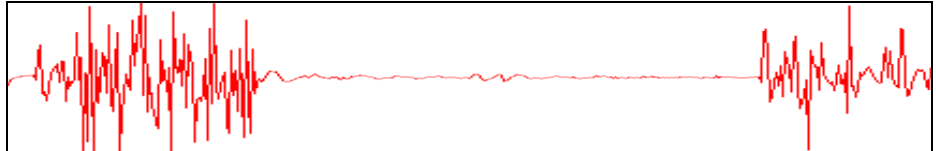


Figure 4 - Unfiltered EMG (20-800Hz) with significant low frequency artifact signals

The optional filter also contains an additional anti-aliasing filter that may be preset on installation to a range of frequencies from 300 to 2,000 Hz. This additional filter can be used to ensure that the output signal from the MA300 system does not contain any signals that might cause aliasing errors. Setting this internal filter will override the backpack filter setting and ensure that the system cannot produce any signals higher than the internal value. This can be set when the system is installed and offers a wider range of filter points as well as a much steeper roll-off.

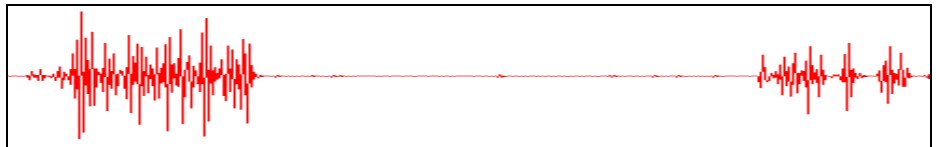


Figure 5 - Filtering the EMG signal (80-350Hz) to remove artifact produces cleaner data.

The effects of filtering the EMG signal are shown in [Figure 3](#) (unfiltered) and [Figure 4](#) (filtered). Both illustrations are the same signals from a fine wire recording of the Tibialis Anterior muscle.

The illustration shows the original sampled EMG data, recorded at 1600 samples per second. This means that the analog data can contain frequencies as high as 800 Hz. The result of filtering the original EMG signal with a band-pass filter set at 80 Hz to 350 Hz are shown in [Figure 4](#). These illustrations were generated using Motion Lab Systems EMG Analysis software together with the C3Deditor analog filter. Demonstration copies of these software packages can be downloaded from the motion lab systems web site at <http://www.motion-labs.com> at any time.

It is important to note that applying a filter to the MA300 signal path will filter all signals passing through the EMG channels in the MA300.

If you intend to perform an electrical specifications test of the MA300 system EMG channels with a device such as the Whisper EMG Test Set then we recommend that low-pass filter in the backpack and the high-pass and low-pass filters in the optional internal band-pass filter are set to their minimum effective settings (20Hz HP and 2kHz LP) and that data is sampled as fast as possible (at least 4,000 sample per second per channel) to reproduce the test signal as accurately as possible.

The four auxiliary research channels

The auxiliary channels are

All MA300 systems, except the MA300-XVI, include an additional four channels

not affected by the optional filter or the anti-alias filter setting.

that can be used for low frequency signals. These four channels have a bandwidth of DC to 120 Hz which makes them ideal for many research applications that require a DC frequency response such as event switches, goniometers, EKG, respiration, and oxygen consumption to list only a few of the possible applications. The low pass frequency response of these channels is fixed at 120 Hz. Any input signals above 120 Hz will be attenuated and will not appear at the output of the MA300. Inputs to all four channels are through a pair of input connectors – one on each side of the backpack and must be within the range of ± 2.5 Volts. A small amount of isolated DC power may be drawn from the subject backpack to power any external interface circuitry or can be used to record event switch signals with an appropriate current limiting resistor.

Please contact Motion Lab Systems if you require a cable to interface to these channels. Goniometers can be connected via a Goniometer Interface Box (GIB) available from Motion Lab Systems.

Event switch signals

MA300 systems with dedicated event channels support the use of up to a total of eight (8) event switches to record gait events such as heel-strike and toe-off. The dedicated event switch interface is designed to work with our standard MA-153 event switch, FSR's (Force Sensitive Resistors), or any common switch device. All event switch inputs are fully “de-bounced” in the subject backpack.

The state of each of the eight (8) event switches (open or closed) is encoded in the dedicated event switch interface and sent to the interface unit as digital signals in ensure signal integrity. On arrival at the MA300 desktop interface unit the event switch output is transformed into two analog outputs that encode the state of four event switches each (left and right feet) as 16 discrete DC levels for each analog event signal output. Note that there is no requirement to use all eight (8) event switches. If your application only requires heel and toe contact information to define a gait cycle then just use two (2) event switches and disconnect the unused event switches. The system will ignore the unused inputs, which will be treated as “open” switches.

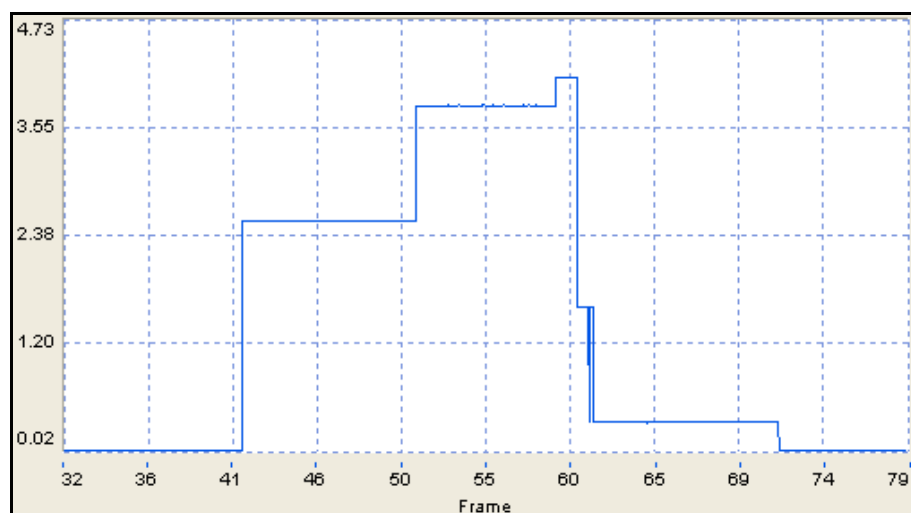


Figure 6 - A typical analog event switch signal indicating multiple switch closures.

The event channels can record any type of binary (on or off) event to indicate

By encoding four switches onto a single analog channel the user is only required to record or monitor a total of two analog channels to observe the state of all eight (8) event switches. Each of the two analog event switch output channels is at zero volts

an EMG activity timing period – on or off, up or down, hit or miss etc.

when all four of its event switches are open. When any one of the four (4) event switches closes, the appropriate analog event switch channel output voltage will increase by an amount determined by the closing switch. Each switch changes the output by a unique value.

This system works because each of the four (4) event switches (left or right side) adds a different DC voltage to its appropriate analog event switch output. When the Heel event switch closes a DC level of 2.500 volts will appear on the analog output for that channel (right or left). Closing the next event switch (generally the fifth metatarsal) will add 1.250 volts to this signal. Thus, the output channel will be at 3.750 volts; the other event switches (first metatarsal and toe) will add 0.625 and 0.313 volts respectively.

By adding the four different voltages, each event switch channel can display the full range of 16 different event switch states. If all four switches are closed, a maximum voltage of 4.688 volts will be seen on the analog output of the event channel. A table of all 16 combinations is shown in appendix A, at the end of this User Guide. Please contact Motion Lab Systems technical support if you need further explanation of this feature.

Event switch sensors

Ten (10) event switches supplied with MA300 systems that support dedicated event channels (MA300-18, -22 and -28). These switches will turn on when a pressure of approximately 50-100 grams of pressure is applied. They can be tested by connecting them to the backpack (via the supplied cable) and pressing them between two fingers while watching the front panel indicator lights. Since the sensors are small, they require a little care in placing the sensors in the right position to record the appropriate event/floor contact. Usually a few practice sessions on a willing subject are all that is necessary to enable you to attach the sensors quickly and accurately.



Figure 7 - A standard Motion Lab Systems event switch.

The sensors each have a two-pin connector on a lead - this connector is designed to make a reliable electrical connection yet disconnect easily should any force be applied to the connection to avoid damage to the sensors. The connector should mate with an event switch cord (sold in packs of eight - Motion Lab Systems part number MA-136) that plug into the event switch cable from the subject backpack. The event switch cable plugs into the subject backpack and has a connector housing at one end that connects to the event switch cables. This housing should normally be taped to the subject's ankle so that the event switch cords and switches can be easily placed to provide the most reliable signals while interfering with the subjects gait as little as possible.

The MA300-X systems do not have dedicated event channels. Event switches are supported on these systems via direct connection to the EMG signal inputs (one switch per EMG channel connector) or into the auxiliary channels on the MA300XII system (two switches per auxiliary connector). Event switches that are connected to the auxiliary channels or the EMG channels do not indicate their status via the DTU front panel lights.

System Displays

Signal Displays

The MA300 desktop unit provides three system status indicators grouped together at the bottom of the front panel. These are two yellow LED indicators that show possible fault conditions and a green LED indicator that should always be illuminated when the system is turned on, indicating that the AC power is connected and the DTU power supply is functioning. Eight individual green LED indicators at the top of the unit display the status of the dedicated event switch event switch channels available on some MA300 backpacks. These lights enable you to immediately check the functioning of event switches connected to the subject via the dedicated event channels.

System Status

The two yellow LED indicators are labeled “No Sig.” and “CRC”. The yellow “No Sig.” LED will illuminate when the desktop interface unit is not receiving a digital signal from the backpack. This would be quite normal if the pack-back were disconnected from the deck-top interface. However, error condition exists if the LED indicator comes on while the backpack is connected. A faulty coaxial interconnecting cable or an internal fault within a system component could cause such an error condition.

The yellow “CRC” LED indicator will be illuminated if the internal digital error checking circuitry detects an error in the incoming signal. The “CRC” light should not be illuminated when the MA300 system is used with a coaxial cable but will light when the radio telemetry option is used. The “CRC” light indicates the small errors of one or two bits in the data signal are being corrected by the circuitry within the interface unit.

If either of the yellow LED indicators is lit when using a coaxial cable to connect the backpack and desk top units you should check the cable connecting the backpack to the desktop unit and contact Motion Lab Systems to discuss the repair of the system.



Event switch indicators

There are eight green event switch activity indicators at the top of the interface front panel that indicate the status of the dedicated event channels that are available on some MA300 backpacks. Each activity indicator lights when its associated event switch closes and, during normal gait (heel, 5th, 1st metatarsal and toe sequence), you will see the indicators light in a moving bar from heel to toe. These lights also enable the user to test each event switch individually and quickly find and replace faulty event switches at any time.

These indicators do not indicate the status of event switches connected to EMG or auxiliary channels on MA300 backpacks when the dedicated event channels are not used.

Backpack indicators

There are only two indicators types on the backpack. These are green PWR indicator that should always be on when the system is operating and blue LED indicators associated with each EMG channel gain control that light whenever the associated channel signal approaches an overload condition. The blue overload LED indicators will light whenever its associated EMG input is within 5% of its maximum operating level. As a result, it is normal for them to light occasionally during use but they should not be continuously lit as this would indicate that the associated EMG channel gain is too high.

The green LED indicator should always be lit – this indicates that the backpack is receiving isolated DC power from the desktop unit.

Fault Detection and Troubleshooting

The MA300 systems are very reliable but if you experience any problems then the following hints may prove useful. Always return any faulty units to Motion Lab Systems or a qualified biomedical engineer for internal repairs.

You can always contact Motion Lab Systems to discuss any potential problems with any of our products regardless of the warranty status or age of the product. There is no charge for contacting Motion Lab Systems to discuss a service or support issue.

Note that it is normal for all the indicator lights to flash ON briefly when AC power is first connected to the system or when the subject backpack is connected to the system or cable.

The Display Unit No Sig light is on.

There is no signal coming from the backpack. Check that the backpack is connected and the green backpack DC OK light is on. If it is OFF then you probably have a broken coaxial cable — replace the cable with a spare and schedule the broken cable for repair as soon as possible. Contact Motion Lab Systems if this indicator remains on after replacing the coaxial cable. Return the unit to your distributor or biomedical engineering department for service.

None of the front panel lights are on.

Is the power switch on? Check the line cord and fuse — at a minimum the green POWER light should be on to show that AC power is applied to the unit and the DC Power Supply is operational. The internal power supply is auto-sensing and will select the correct AC voltage range - no user adjustment is required. Contact Motion Lab Systems if none of the indicators light when AC power is connected and the desktop is turned on. Return the unit to your distributor or biomedical engineering department for service.

The CRC light is on but the No Sig light is off.

Check that the backpack is connected to the system via the coaxial cable for testing. If the backpack is connected and appears to be functioning then you may have an internal fault in the system. The CRC light shows that the digital signal channel is generating an error. Contact Motion Lab Systems if this indicator remains on while the backpack is connected to the system. Return the unit to your distributor or biomedical engineering department for service.

The blue LED indicators on the backpack are ON although the subject is inactive.

Select a lower channel gain for the associated EMG channel - if the light does not extinguish then you may have a defective EMG pre-amplifier. Check that the pre-amplifier has been applied correctly – if you cannot see what the problem is then replace it with a spare and test it later.

The software package used to analyze the EMG signals from the MA300 does not find the correct gait cycles.

Check that the analog event switch signals are assigned correctly so that the left side EMG signals are being analyzed with the event switches on the correct event. Read your EMG analysis software manuals to determine how the software determines gait cycles. Contact Motion Lab Systems technical support if you cannot resolve the problem.

The EMG signals recorded are very small although the blue indicators on the backpack show that large signals are being recorded.

Check that your ADC sampling system gain is set correctly to match the input level expected by your ADC recording system. Typically when you have this problem you will find that the ADC sampling system has been set to respond to a ± 10 Volts (i.e. 20 Volt range) signal. If in doubt, use an oscilloscope to confirm the MA300 output levels. The correct analog signal range for all MA300 signals is ± 5 Volts for all EMG and event switch channels.

The recorded EMG signal appears to be distorted, with EMG activity that doesn't match the expected signal.

Check that the analog sample rate of the Motion Capture or recording system is fast enough – MA300 systems without the anti-alias bandwidth filter must be sampled with a rate of at least 2000 samples per second while the sample rate for the MA300 systems with the anti-alias switch will depend on the setting of the anti-alias filter. The analog sample rate must be at least twice the anti-alias filter setting to avoid aliasing errors in the recorded signal.

The system is functioning but no EMG is recorded on any external device.

Check the connecting cable with an oscilloscope to ensure that the cable is correctly connected and that EMG signals are present at the input of the ADC sampling system.

Some EMG channels work but others do not have any EMG signals.

Check the analog signal connections from the back of the MA300 desktop unit through to your measuring/recording system. Almost all 'lost channel' complaints are due to problems with the analog signal cables and connectors. If this does not cure the problem then record an example file (C3D format if possible) and send it to Motion Lab Systems for analysis.

The system appears to be functioning but the signals recorded are very large or very small compared to another EMG system such

Check the settings of the gain switches for the channels that appear to have problems. Increase the gain for any low level signals by turning the gain switches clockwise to higher numbers, decrease the gain by turning counter clockwise to select a lower number on the gain switch.

as the MA-100.

The MA300 system appears to be functioning but ALL of the EMG is recorded with very large amounts of noise and AC interference.

Check the connecting cable with a multi-meter to ensure that there are no broken connections. Check that the signal return (output pin #17) is connected correctly and that you are not using the Chassis Ground (output pin #25) as a signal ground.

If you have noisy data use a disposable electrode to provide a ground reference. Apply the electrode to the subject skin surface and connect to the safety DIN connector adjacent to the coaxial cable connector on the subject backpack.

Use an oscilloscope to measure the signal present at the MA300 analog output connector with the unit turned on and connected to the backpack but without any EMG pre-amplifiers connected to the backpack. The AC noise component of the output signal should be less than 10mV (a small DC offset may be present). Signals greater than 10mV may indicate a grounding problem or a fault within the MA300 EMG system. Check that you are recording/sampling the EMG at a high enough sample rate and send a sample data file (C3D format if possible) to Motion Lab Systems for review.

The MA300 system appears to be functioning but some of the EMG is recorded with noise and AC interference in the signal.

When some EMG channels are noisy but other EMG channels appear fine this always indicates a problem with either the pre-amplifiers or the electrode/skin interface on the subject.

Test the preamplifiers on the problem channels - do they produce a good recording on another muscle? If so the then problem is poor skin contact at the original electrode site – either the preamplifier electrodes are not making good mechanical contact with the skin or else the skin is dry and a poor signal conductor. Rubbing a very small amount of electrode gel or a water based hand lotion into the skin will almost always improve the signal if the skin is dry and/or flaky.

Intermittent problems are usually a result of broken wires – commonly at either the backpack connector or the entry into the preamplifier body. In this case return the preamplifier for repair.

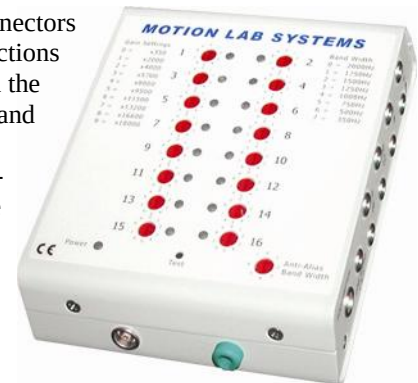
Using the MA300

Connections

Each MA300 system consists of a backpack, carried by the subject using one of the belts or jackets supplied, and a desktop interface unit. These two units are connected by means of the lightweight coaxial cable supplied with the system or via the radio telemetry option. The backpack comes with EMG pre-amplifiers (six, eight, ten or sixteen - depending on the model in use), a coaxial connecting cable, and an analog signal cable together with a belt or jacket to support the backpack during use. MA300 backpacks that support the dedicated event channels are also supplied with event switch connection cables, and event switches. Event switches are optional with the MA300 EMG systems that lack the dedicated event channels.

The subject backpack

The backpack unit (BPU) has two rows of connectors on either side of the casing that provide connections for the EMG pre-amplifiers and, depending on the type of backpack, auxiliary research channels and the event switches. Some MA300 backpacks have eight dedicated event channels via two 5-pin LEMO connectors, one on each side of the backpack. The EMG and auxiliary research connectors will vary depending on the options selected when the system was purchased – these can be either 4-pin LEMO or 4-pin BINDER connectors.



There are no subject connections or user adjustments inside the backpack cover – all connections and controls are accessible without opening the backpack.

Each side of the backpack will have a number of EMG connectors – three, four, five or eight, depending on the backpack model. The EMG inputs are numbered with odd channels on the left side of the backpack and even numbered channels on the right side. In addition to the EMG channels, each side of the backpack may have a connector for two auxiliary research channels and four event switches. You should not connect any EMG pre-amplifiers to either of these inputs.

The subject backpack has a number of miniature LED indicators. The green POWER light should be on whenever the pack-pack is connected to the interface unit and shows that DC power is supplied to the system and the internal power supplies are functioning correctly. In addition to the power light, each EMG channel has a blue

LED indicator that will flash if the associated EMG signal is within five percent of an overload condition. Flashing occasionally during an experiment is normal for these lights as brief peaks of muscle activity occur during contractions.

In the center of the subject backpack are two rows of gain controls switches. These allow the user to vary the gain of the individual EMG channels to optimize the signal levels. Each control is a ten-position switch that changes the channel gain, allowing a wide range of signal input levels. Each control can be easily adjusted with a small flat-blade screwdriver.

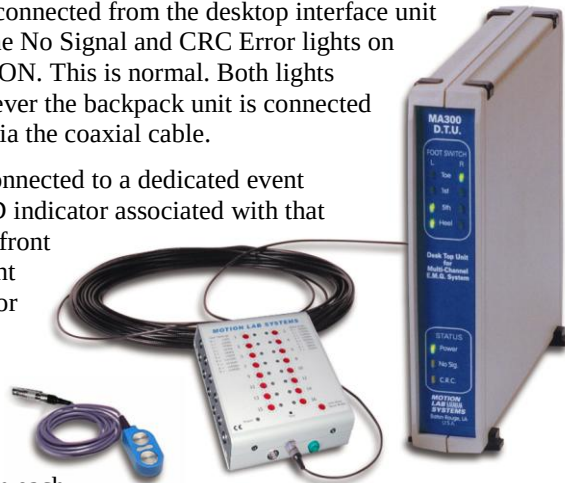
The TEST push button, below the gain switches, is recessed to prevent inadvertent operation. When this button is depressed a standard test signal is applied to all of the EMG channels allowing the system to be calibrated so that the gain used for each channel can be automatically recorded.

Some backpacks include a variable low pass filter – this is marked “Anti-Alias Bandwidth” and should be set to the desired EMG signal bandwidth prior to recording any EMG signals.

The interface unit

When the coaxial cable is disconnected from the desktop interface unit (DTU), you will notice that the No Signal and CRC Error lights on the desktop interface unit are ON. This is normal. Both lights should be extinguished whenever the backpack unit is connected to the desktop interface unit via the coaxial cable.

Whenever an event switch, connected to a dedicated event channel closes, the green LED indicator associated with that event switch will light on the front panel. There are a total of eight event switch indicators, one for each switch circuit, so that up to eight dedicated event switches may be monitored simultaneously. Note that although the system can monitor up to four switches on each event, few software packages require all four switches for gait analysis. If all you require is gait timing information then you may find that you only need the heel switch to provide basic gait cycle information. Dedicated event switch channels are a feature of some MA300 backpacks while other backpacks support event switches via the auxiliary or EMG data channels which are not monitored on the DTU front panel.



The EMG pre-amplifiers

The standard preamplifiers supplied with the MA300 system have a gain of x20.

Motion Lab Systems offers a range of different preamplifiers to accommodate almost any EMG data collection requirement so it is important to select the correct type of preamplifier for the subject and data collection conditions. MA300 systems are available with a range of preamplifiers – normally our standard MA411 surface preamplifiers are supplied but systems may include several different preamplifier types. Each type of preamplifier is available with either LEMO or BINDER connectors – if you order additional preamplifiers at any time then you should make sure that you request the correct type of connector for your system. LEMO connectors have a metallic case while BINDER connectors are black plastic. All preamplifiers have similar specifications.

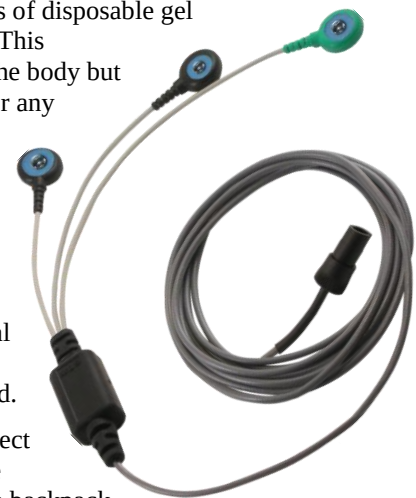
MA411 preamplifiers are high performance EMG amplifiers with two sensor disks separated by a single ground reference bar. These preamplifiers are easy to use and can generally be quickly strapped or taped over any surface muscle on the limbs. They do not require gel and work well even on moderately hairy subjects without requiring shaving or extensive skin preparation. These preamplifiers can usually be used without a separate ground reference electrode although we recommend a ground reference electrode if AC line noise is a problem.



The MA411n preamplifier style is identical to the MA411 but lacks the central ground reference bar and requires that a separate ground reference electrode is used. This preamplifier style is preferred in some situation where high levels of static or AC line noise is a problem.

The MA416 preamplifier is designed for use with fine-wire electrodes and has two thumbscrews that can be used to connect fine-wire electrodes. These preamplifiers require a separate ground reference electrode to avoid AC line interference problems in the recorded EMG signal. MA416 preamplifiers are designed to withstand the stimulation pulses produced by any muscle stimulator, allowing the electrode placement to be verified after wires are connected to the preamplifier.

The MA420 preamplifiers feature a waterproof body and standard “snap lead” connections for use with many different types of disposable gel silver/silver-chloride (Ag/AgCl) electrodes. This preamplifier style can be used anywhere on the body but is particularly suitable for upper body work or any situation where perspiration or moisture is a problem.



It is generally best to attach the backpack behind the subject using the jacket or belt provided with the system although some data collection protocols may require that the backpack is mounted on the chest. Additional belts and jackets in different sizes may be ordered from Motion Lab Systems as required.

Once the backpack has been fixed to the subject you can attach the EMG pre-amplifiers to the subject. Note that there is no need to have the backpack connected to the coaxial cable from the interface at this stage. It can be connected at any point before the collection of data - you do not need to switch off the interface unit when you connect or disconnect the backpack or attach the EMG pre-amplifiers to the subject. Many people use our small plastic bead markers on the individual preamplifiers cables identify individual pre-amplifier leads. Each bead marker clips over the pre-amplifier cable and identifies the cable by color and can help ensure that each preamplifier is connected to the correct channel.

Surface EMG

If the skin surface appears dirty or greasy then you will need to “prep” the surface with an alcohol soaked cleaning swab. When you have found (or land marked) the correct position for the pre-amplifier on the muscle you should tape the pre-amplifier in place using Micropore® or similar hypoallergenic tape to hold the preamplifier in

place on the muscle. The preamplifier can then be wrapped tightly against the muscle by a length of Coban[®] or similar sports wrap – make sure that you use Latex free tape if you anticipate that your subject may be Latex sensitive. The additional wrap of Coban[®] will hold the preamplifier disks tightly against the skin surface and ensure that they do not move during the EMG tests as unwanted motion over the skin surface will cause low frequency noise to appear in the EMG signal. If the pre-amplifier has been applied properly then you should see two circles impressed into the skin when the pre-amplifier is removed at the end of the session. These marks will generally fade within 10 to 20 minutes. Subjects with particularly sensitive skin or freshly shaved areas may find that the marks last up to 24 hours.

It cannot be stressed too much that this is the most critical stage in the preparation of the subject if you are to obtain high quality EMG recordings. Surface pre-amplifiers will provide good signals from most of the muscles involved in gait if sufficient care is taken in preparing the subjects skin and applying the pre-amplifiers.

It is most important to make sure that the preamplifiers cannot move of the surface of the skin as the subject walks or moves. All motion artifact problems with MA300 systems can be traced to noise generated by the movement of the preamplifier on the surface of the skin during the recording. Likewise AC line noise problems are either caused by a faulty preamplifier or electrode contact issues where one electrode disk is not making a good connection with the subject. The digital nature of the MA300 system eliminates the possibility of recording motion artifacts from cable motion, radio frequency noise, or electromagnetic fields.



EMG preamplifiers manufactured by Motion Lab Systems Inc., are fully protected from accidental static discharge and cannot be damaged by muscle stimulators.

Fine Wire EMG

If you are using fine-wire electrodes (sometimes called “needle electrodes”) then the wire should be inserted into the muscle by a qualified therapist or doctor and the insertion needle removed. If you want to stimulate the muscle to check the electrode insertion then this may be done *after* the wires are connected to the EMG pre-amplifier. The Motion Lab Systems pre-amplifiers contain protection circuitry that ensures that they cannot be damaged by muscle stimulation signals so you can easily stimulate a muscle once the wire electrode has been inserted and connected to the preamplifier.

Commercial fine-wire electrodes are always supplied in sterile packaging and should be ‘ready to use’ however, if you are making your own fine-wire electrodes you may find that you need to remove the insulation from the ends of the wire that will contact the EMG pre-amplifier. This can be done either with a strip of abrasive paper or with a flame as the insulation will usually vaporize easily.

Motion Lab Systems MA416 preamplifiers are supplied with a set of nylon thumbscrews which are ideal for attaching both fine-wire or disposable gel electrodes. Options available for the MA416 preamplifier include pairs of springs contacts or medical-grade stainless steel thumbscrews that allow direct stimulation of indwelling fine wire electrodes.

You may also use a disposable subject ground electrode connected to the backpack unit ground reference socket by the coaxial cable connection. This helps to maintain the pre-amplifier common mode rejection ratio or C.M.R.R. (i.e., it helps keep the

noise and hum levels low). The backpack connection will accept most standard disposable monitoring electrodes with an IEC-60601 'TouchProof' connector that meets the performance standard for Electrode Lead Wires and Patient Cables, in Title 21 Code of Federal Regulations (CFR), part 898.

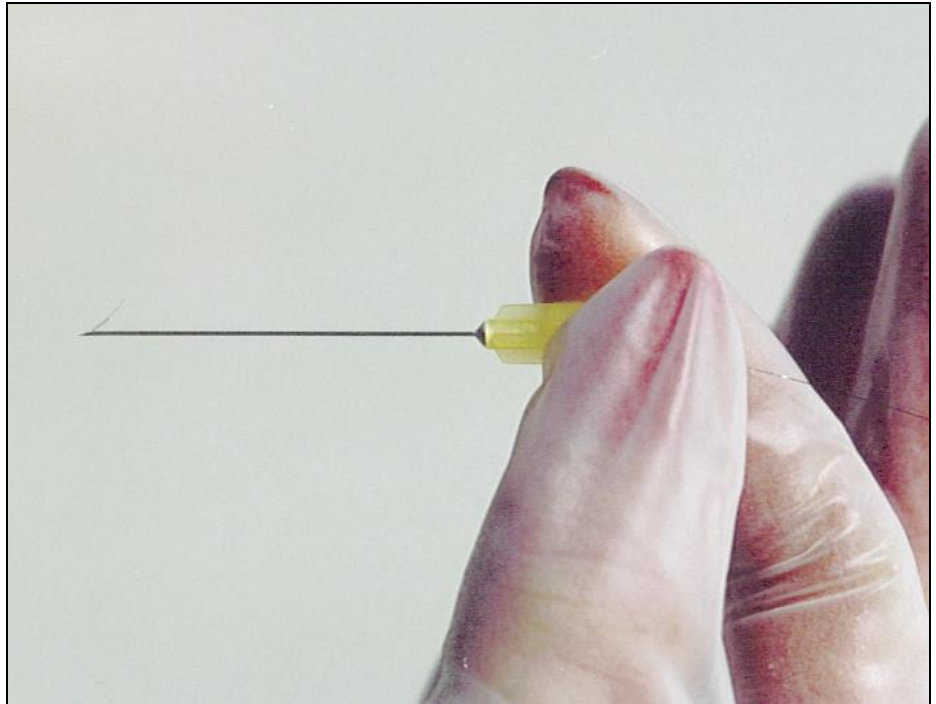


Figure 8 - fine-wire electrode prepared for insertion into the muscle.

The EMG pre-amplifiers supplied with the MA300 should last a long time in regular use. With care, especially in the removal of the pre-amplifier from the subject after the experiment, they may last many years. If the pre-amplifiers are abused by pulling them from the subject by their leads then their life will be considerably shortened. Replacement EMG pre-amplifiers are available through your local distributor, or directly from Motion Lab Systems Inc. Please note that Motion Lab Systems provides only a thirty-day warranty on the pre-amplifiers and event switches and that this warranty does not cover normal wear and tear or abuse.

Using Fine-wire Electrodes

Check the expiration date on the fine-wire needle packaging and verify that the fine-wire sterilized packaging is intact. Follow local site procedures and discard any packages that have expired, or are not sealed and intact.

Prepare the subject for the insertion by cleaning and sterilizing the insertion area as appropriate for the intended test, taking all necessary precautions to prevent infection and or contamination.

Packs of 10 'Ready-to-Use' sterile fine-wire electrodes are available from Motion Lab Systems with 30mm and 50mm cannulas.

Remove the fine-wire electrode from the package and visually inspect both ends of the electrode wire without touching or contaminating the wires or needle. This may require holding the electrode against a light surface under a bright light and using a magnifying glass. Both of the hooked ends should be insulated to within 2mm of the tip with the remaining wire being exposed - the bare ends should be staggered, not in contact with each other, and snug against the point of the needle. There should be no kinks throughout the length of the wire that might cause the wire to break when removed from the subject after the test. The opposite ends of the wires should have approximately 6mm of uninsulated, exposed wire for connection to the recording

interface.

Refer to your anatomical guides as appropriate, locate the desired insertion point and insert the needle into the muscle smoothly to the desired depth to place the hooked wires into the target muscle.

Carefully withdraw the needle, leaving the fine-wire pair in place within the muscle and connect the un-insulated, free ends of the wires to the inputs of your recording system. Use small pieces of tape to secure the wires at the insertion site and against the skin to minimize any movement of the wires, or strain at the insertion point during testing. This helps to minimize signal artifact and noise.

You may optionally check the wire placement within the muscle by applying a stimulation pulse using a suitable approved nerve stimulation device. Always start with a low stimulation level and gradually increase the level while observing the target muscle - if the wire is placed correctly then a small twitch will be observed in the correct muscle when it is stimulated. Motion Lab Systems pre-amplifiers can withstand stimulation pulses without problems but if you are using another system then you should check with the manufacturer to ensure that a stimulation pulse will not damage their equipment.

Connect an external ground reference electrode to the subject and perform the EMG test, visually monitoring the EMG signal quality during the test if at all possible.

After the EMG test has been completed, the recording equipment should be disconnected from the subject. The fine-wire electrode wires can then be removed with a gentle, smooth and steady pull. This will usually bring the electrodes out painlessly as the wires are so fine and delicate that they offer little resistance to their removal.

Immediately inspect the wires after removal to ensure that the wires have been removed intact from the subject - the wires are nominally 200mm in length ± 3.125 mm. Occasionally small parts of the wire will remain in the muscle after a test but provided that the wire fragments are small (less than a couple of millimeters) this is not normally a cause for concern.

Swab the wire removal site with a sterilizing solution, apply a suitable sterile covering if necessary and dispose of the used needle and wires in accordance with local safety policies.

The event switches

The MA300 is designed to record event contact with the floor. The sensors for this are small disks that are less than a millimeter thick. MA300 systems that support dedicated event channels are supplied with a total of ten 30 mm event switch sensors while they are available as an optional extra with systems that do not have dedicated event channels. Event switches can be used with MA300 systems that do not support dedicated event channels by connecting the event switches to either the auxiliary analog channels or directly to an EMG data channel using the appropriate cable.

These sensors act as a switch when they are connected to the MA300 and a pressure is applied. You can test them with a continuity tester in the same way that you would a regular switch.



Figure 9 - A standard event switch.

Each switch has a thin connecting tail, 100mm long, that ends in a small, two-pin connector. The switches should be taped under the foot, using a hypoallergenic tape, such as Micropore®, so that the tail of the switch with its connector comes around the side of the foot and away from the contact area of the foot. The event sensor may then be connected to the backpack.

MA300 systems that record events via a set of eight dedicated switch inputs feature “debounce” processing within the backpack to ensure reliable event switch detection. These systems use a foot switch cable (MA135 with a five pin LEMO connector) and individual event switch cords to connect the event switches to the system.

All MA300 systems optionally support events through the auxiliary channels (MA300-XII), or via an EMG data channel (MA300-XVI), and use different event cables to connect the event switches to the systems. Event switches and cables are only supplied with the MA300 systems that support dedicated event channels.

Note that the event switches and their associated event cables are intended to be “disposable” items. Replacement event switches, connecting cables etc., are available through your local distributor, or directly from Motion Lab Systems Inc. Please make sure that you specify the correct cables when you order replacement items.

The coaxial cable

The 18m coaxial cable (p/n MA133) that connects the backpack and the interface has been selected to encumber the subject as little as possible but it is not designed to last forever. Under normal operation it will eventually fail and should be replaced every year or so, depending on usage. Additional cables may be purchased from Motion Lab Systems if needed or the original cable may be returned for repair.



The condition of the coaxial cable is easily checked with an ohmmeter.

The coaxial cables supplied with the system use industry standard RG-174U coaxial cable. A standard cable is 18 metres long although this length is not critical and cables may be assembled with nonstandard lengths between 2 and 35 metres. Each cable uses identical coaxial LEMO connectors at each end.

The cable is a simple coaxial cable and can be tested for continuity with any common ohmmeter – normal cables will have low impedance from one end to the other (5-10 ohms is normal). There should be a very high impedance (greater than one million ohms) between the inner conductor (central LEMO connector pin) and outer shield (LEMO connector case).

Making an EMG recording

Getting started

Your MA300 EMG system can be used to collect EMG signals in a variety of situations and as a result it is not practical or very useful to try to provide instructions at this point for the system under all conceivable circumstances. Therefore this chapter will describe the use of the system in a single setting — that of a Gait or Motion Analysis Laboratory. We assume that by this stage the MA300 has been connected to a computer or other recording device and that the system has been tested to check that everything is working.

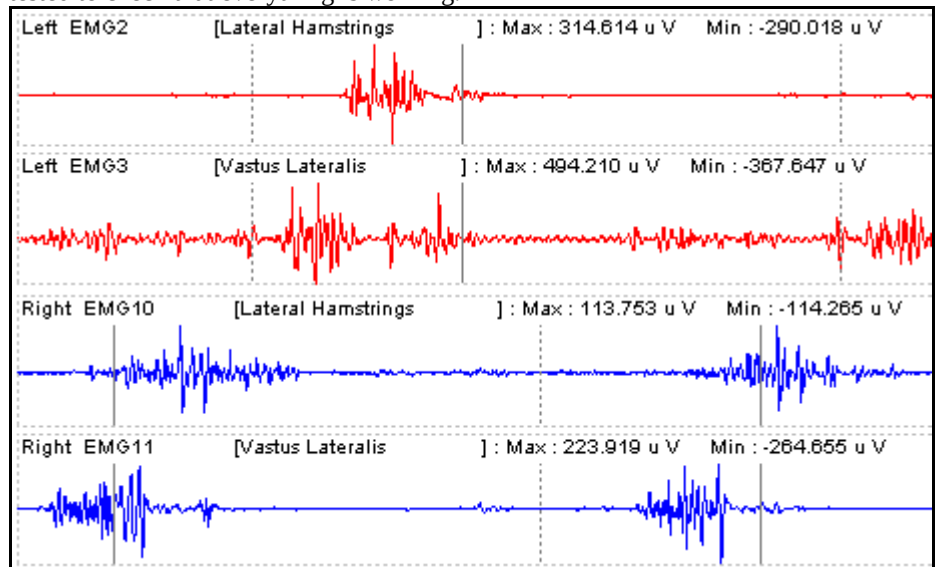


Figure 10 - Typical MA300 raw EMG recordings from human gait

The usual procedure in Gait Testing is to have the subject walk, several times, in a straight line over a distance of four to seven meters (roughly 10-20 feet) while their movement is recorded for later viewing or processing. Information from force plates and 3D trajectory data may also be collected simultaneously when the EMG system is used in a Gait Laboratory.

Start the subject from the end of the walkway or data collection area and ask them to walk as they would normally - let the subject reach their normal walking speed before you start to record any data. Since they will be trailing the MA300 coaxial data cable behind them it is often useful to tape two colored arrows at either end of the walkway — these serve to show the subject which direction you would like them to turn so that they clear the trailing cable as they return down the walkway. You can

use green tape at the start line and red at the stop line - the subject will rarely notice the trailing cable at all and these arrows will help eliminate any unnecessary tangles.

If you are planning to record kinetic data from a force plate while you record EMG then you may find it convenient to place several different colored "start" lines at about six inch intervals to enable you to adjust the subjects starting position to obtain a good force plate strike with one foot. In this case you may have to walk the subject several times at the start of the test to decide the correct starting line so that they have a good chance of hitting the force plate cleanly with a single stride.

Subject Preparation

Remove preamplifiers from unused EMG channels if possible. There's no need to use all of the available channels if they are not required for the study.

The preparation for EMG testing should always begin before the arrival of the subject. You will need to decide where to place preamplifiers and whether the study will be bilateral or unilateral. Using a single MA300 you can study between six and sixteen individual muscles (depending on the model that your lab has purchased) and although the MA300 subject backpack is marked on the assumption that you will record a number of muscles of each side of the body, this is not fixed in any way.

If you are also taking kinematic data with a Gait Analysis system then you will also need to prepare the marker sets (usually small retro-reflective balls) that you will be using. Always test your system (MA300 and kinematic collection if used) before the subject arrives — any problems are much easier to diagnose and fix before the testing starts.

The muscles that will be monitored during your study are dependent on the diagnosis of the subject and the extent of lower limb involvement. It is best if a decision about which muscles are going to be evaluated is made before the arrival of the subject — often this is done by, or in consultation, with the physician. You may find it useful to set up a muscle protocol to be monitored for each different diagnosis but use this as a guide only as each subject will be different. Some typical examples of diagnosis related protocols for a ten-channel MA300 might be:



- **Spastic Diplegia** - Five muscles on each limb - Tibialis Anterior, Gastrocnemius, Rectus Femoris, Medial Hamstring and Adductors.
- **Myelomeningocele** - Either a bilateral study - five muscles on each limb (Rectus Femoris, Medial and Lateral Hamstring, Gluteus Medius, Gluteus Maximus) or for a unilateral study use all ten muscles eg. Tibialis Anterior, Gastrocnemius, Posterior Tibialis, Peroneal, Rectus Femoris, Medial and Lateral Hamstrings, Adductor, Gluteus Maximus and Gluteus Medius.
- **Hemiplegia and Head Trauma** - Tibialis Anterior, Gastrocnemius, Peroneal, Posterior Tibialis, Vastus Lateralis, Rectus Femoris, Medial Hamstrings, Adductors, Gluteus Maximus, Gluteus Medius

Each MA300 EMG channel should normally be assigned to the subject's side and muscle on which the preamplifier will be placed. This information must be recorded as the preamplifiers are applied to the subject, as this information will be required for subsequent analysis of the recorded data. It is useful to keep a copy of this information, with any relevant observations in the subject's chart to prevent any

memory lapses later. See the sample data record sheet at the end of this manual for an example of a typical EMG information recording form. The use of Bead Markers on individual EMG preamplifiers greatly assists in the assignment of EMG preamplifiers to a specific muscle.

The preparation and application of the EMG preamplifiers will be different depending on the subject. Adult subjects usually only require an explanation of function of the preamplifier in recording their muscle activity while with young children allowing them to touch both the preamplifiers and event switches before placement on their body may be beneficial. This will allow them to learn that this test will not hurt them and may help gain their cooperation and assistance in the testing.

The Motion Lab Systems EMG preamplifiers contain circuitry to protect them from damage by static discharge so that they can be easily handled without any special precautions. Most EMG preamplifier failures are due to mechanical damage that is not covered by the system warranty (e.g. cutting the preamplifier cables with scissors) – static discharge will not harm them.

Event Switch Application

We're going to discuss gait activity in this section but the MA300 can record event data from almost any repetitive activity.

Event switches are used to define periods of physical activity during the EMG recordings so that EMG activity can be correlated to physical activity. Multiple periods of physical activity can be averaged together when several periods of activity are defined in this way. Typically events are defined by the closure of small switches, activated by some physical motion but periodic activity can also be defined by rotational position or any other repetitive activity.

The Motion Lab Systems event switch is a round Mylar disk containing a pressure sensitive sensor connected to a small two pin socket on a Mylar extension lead. MA300 systems support almost any type of event switch that generates an event via a switch closure or, in the case of a force sensitive resistor (FSR), a large change in the resistance of the device. Motion Lab Systems supports the use of FSR devices but does not recommend them due to reliability issues with FSR devices when used to detect gait events.

If you are using a motion capture system that can detect gait events from the kinematic and kinetic data then you may not need to use event switches.

When used in gait analysis, MA300 backpacks that include dedicated event switch channels can use four event switches applied to the plantar aspect of each foot, on the great toe, first and fifth metatarsal heads and the heel. Systems that do not contain any dedicated event channels generally use event switches as an optional feature to record basic heel contact and optionally, toe off. Event switches on these systems must be connected to either the auxiliary channels or an EMG data channel.

It is often easiest to attach the event switches to the subject first, before applying the EMG preamplifiers. This can be done with the subject reclined and the ankle supported by a small towel so that you have easy access to the entire foot. If you are using the event switches together with a motion capture system that uses markers then it is best to apply the event switches before the subject markers are placed if you intend to record both motion and EMG simultaneously. This allows for the event switches to be placed and the connecting wires attached so that they avoid the joint markers.

Plug each event switch cable into the appropriate event switch channel on the cable from the EMG subject backpack and test each event-switch as it is connected. Many EMG software analysis systems will require that each event switch



be connected to the correct channel so it is important to make sure that the event switch applied to the great toe is connected to the right input (generally #1 on the event switch connector cable).

Note that while the descriptions below list the anticipated locations of all four event switches you will rarely need to use all eight event switches on every patient. Most clinical analysis packages require only the heel event switch (#4 below) to determine gait cycle timing — if the great toe switch is available then "toe-off" information can be calculated in addition to the basic gait cycle timing.

- #4 — Heel Switch - The heel event switch should be placed in the center of the fat pad under the calcaneus. Special attention should be made to placement and method of attachment to the foot. The connector of the event switch should be brought around the medial aspect of the foot using two pieces of two-inch wide tape providing secure attachment of the event switch to the foot. Tape should cover the heel and continue up the side of the heel medially and laterally.
- #1 — Great Toe Switch - Place the switch in the center of the fat pad under the distal phalange. The connector and cable should be placed along the medial aspect of the toe and pointing in the direction of the first metatarsal before the switch is attached. Use one to one and a half inch hypoallergenic tape and place along the length of the event switch leaving extra tape at the large end. This places the circular portion of the event switch under the weight-bearing portion of the great toe. This is dependent upon the weight-bearing pattern of the subject. Subjects with extreme valgus may require the event switch to be placed more medially.

If your software analysis package does not require the first and fifth metatarsal event switches then there is no need to apply these event switches to the feet — this can save valuable time during the initial subject preparation.

- #2 — First Metatarsal Switch - If used, this is usually placed over the base of the first metatarsal head as palpated on the plantar aspect of the foot. The connector and cable should be directed towards the dorsum of the foot and pointed slightly posteriorly before the switch is attached. It is usually easiest to take 2 inch hypoallergenic tape and tape from the middle of the bottom of the foot around the side to the top of the foot.
- #3 — Fifth Metatarsal Switch - If used, the event switch should be placed just on top of the fifth metatarsal as palpated on the plantar aspect of the foot. The connector and cable should be directed towards the dorsum of the foot and pointed slightly posteriorly. Tape for the first and fifth metatarsals should be placed along the entire plantar aspect of the foot and wrapped around to the dorsum of the foot both medially and laterally. This will help avoid damaging the event switches if the subject drags their foot during a walk.

The same procedure should be followed for each foot - note that the event switches can have either side placed next to the skin, they respond to pressure equally from either surface. All connectors and cables should be attached both to the dorsum of the foot and again to the distal and anterior aspect of the shank, remembering to leave some slack in the wire over the ankle joint to allow for movement.

Once the switches have been connected to the subject backpack, and thus to the interface unit, it is beneficial to check event switch placement by pressing the event switch on the bottom of the foot and watching the individual lights on the interface unit that represent the state of each event switch. The light for each event switch should be off when there is no pressure applied to the switch. The light should turn on when the event switch is pressed lightly and must also turn on when the subject

stands on the appropriate limb. Testing of the event switches as they are applied, at the beginning of the test, will facilitate faster subject testing later.

You may find that carefully pulling a sock over the foot after fitting the event switches will protect the switches and cables without affecting the subject gait. This may prolong the life of the event switches by protecting them from rubbing and dragging directly on the floor.

Event switches can also be applied to the bottom of the subjects shoes - if the shoes (or orthoses) are being used in the testing you may get better results this way since event switches inside the shoe can be compressed between the sole and shoe and may always show as "on" although the foot is off the floor.

It is necessary to make certain that the point of application best represents the anatomical position it is documenting and that the shoes actually apply pressure on the ground at that point. The patterned shoe soles of many running shoes may make it difficult to place the event switch so that it fires consistently - if this is a problem you may want to dispense with the first and fifth metatarsal event switch and use only heel and toe switches to define the gait.

Points to Remember

- All the edges of the event switches should be covered with tape to prevent damage to the Mylar sensor during the test. It may be convenient to allow the subject to wear a sock over the foot during the test to protect the event switches from damage.
- Leave some slack in the event switch cables where they cross the ankle joint to prevent the switch becoming disconnected during motion.
- Modify the marker placement instructions if the subject has foot deformities so that the event switches are placed on the weight bearing surfaces of the foot to define initial contact and terminal contact.

Cleaning the skin and the preamplifier site

There is no need to abrade the skin surface to obtain good quality EMG recordings.

Do not use electrode gel directly on the EMG preamplifiers as it may cause poor recordings

The muscle belly should be cleaned with alcohol before EMG preamplifier or electrode placement. This rids the skin of oils that increase impedance, producing artifact and poor recordings. Although shaving hair from the legs for EMG preamplifier placement is not necessary, it may be beneficial to help decrease the discomfort when the tape is being removed. It is strongly recommended that the skin surface around the preamplifier site is NOT abraded.

A simple cleaning is all that is required to obtain clean EMG signals - any abrasion of the skin surface can cause "weeping" that may short out the EMG preamplifier inputs. While this will not cause any damage to the MLS preamplifier it will usually produce poor, low quality EMG recordings.

Dry or flaky skin is not conducive to good quality EMG recordings – when working with subjects with dry skin, or in very dry conditions, it will help if the preamplifier site is conditioned with a small amount of electrode gel or any water-based skin lotion. Always wipe the surface of the subjects skin to remove all traces of excess gel or lotion when moisturizing the preamplifier site.

Preamplifier placement

Once the muscles to be studied are identified, placement of the EMG preamplifiers may begin. Plug in each preamplifier as you go along to avoid any mix-up of the preamplifier cables later. It is usually easiest to begin at the bottom of the leg and

work your way up. Muscles such as the tibialis anterior and gastrocnemius are easy to put on when the subject is sitting. Anterior muscles such as the quadriceps group and the adductors follow — rolling the subject over onto their stomach may then be easiest if they are small and/or have difficulty standing to place the preamplifiers on the hamstrings, and glutei muscles.

Placement of preamplifiers can be determined by using *The Anatomical Guide for the Electromyographer*. Although this guide is for fine wire placement, it provides tests to determine action and descriptions of optimal placement and is very useful when first starting to use a clinical gait system.

It is necessary to get the subject to try to perform the action of the muscle to which is responsible. This will help in assuring accurate preamplifier placement, ensuring that the EMG preamplifiers are being placed over the muscle belly. The preamplifiers are generally secured by using 1-2" hypoallergenic tape over the preamplifier. A couple of short (4" strips of tape) should be used first to help maintain the preamplifier in place until it can be further secured by wrapping longer strips of tape or Coban around the limb to ensure that all of the stainless steel preamplifier contacts maintain a constant connection with the skin surface. This is usually best done after all the preamplifiers have been applied but under some circumstances (uncooperative subjects etc.) you may find it easier to tape up the preamplifiers as you go along.

Subject Testing

Once all of the EMG preamplifiers are secured, you will need to have the subject perform some trial walks. Have the subject walk around the room at their natural pace and record a test session that will allow you to evaluate and check your preamplifier positioning and the signal levels from each muscle. Check that each muscle is recording a good clear signal and adjust the gain levels for any EMG channel that appears to have either too large or too small a signal. Review this data before starting the full gait analysis or test session - correcting errors in preamplifier placement is much easier before the session starts than having to perform the entire session again later to correct a minor error.

Make sure you are certain that you are happy with the signals you see as the subject walks. Have the subject walk one trial and then view the data using either the EMG Graphing or EMG Analysis software supplied with your MA300 system or your Gait Analysis data collection system. This step is extremely important to ensure that good data is being collected before too many trials are done and the subject becomes tired.

Once you are certain that the data that you are recording is good, continue with as many trials as deemed necessary. Usually you will want to try to record at least three or four gait cycles in each trial. For the EMG analysis it is not usually necessary that all these gait cycles occur within the area recorded by any video or kinematic analysis system that you may be using. If the subject is using orthosis you may need to take several runs of data both with, and without the orthosis. Don't forget to record which trials use orthosis and which trials do not — record any other conditions as they occur or video tape the entire session.

In general, three trials per condition are recommended but allow for the subject's strength. After three trials are performed, preamplifiers can be moved to monitor more muscles bilaterally if you only have a six to ten channel MA300 system.

When data collection has been completed, you should check that you are able to analyze at least one of the EMG datasets recorded before you start to remove the preamplifiers from the subject - pay particular attention to the event switch data since this is required to define the gait cycle and EMG activity cycles.

Radio Telemetry

Using Radio Telemetry

The MA300-RT option operates within the 2.4GHz ISM band and does not need an operating license. You can skip this chapter if you have not purchased the Radio Telemetry option.

The MA300 Radio Telemetry option consists of two units that are supplied when this option is purchased. These are a radio transmitter and battery pack (called the transmitter) and a corresponding receiver. The radio telemetry system works in the public 2.4GHz Industrial, Scientific and Medical band (ISM) and therefore does not need a license. The system does not use Wi-Fi protocols and will not show up if you scan for Wi-Fi channels while the MA300 EMG telemetry option is in operation. The 1.2Mbps data stream from the transmitter to the receiver is encrypted before transmission and decrypted in the receiver making this a secure transmission link that can not be intercepted via other systems operating in the Wi-Fi band.



Figure 11 - The MA300-RT telemetry option replaces the standard coaxial cable.

The radio telemetry option can be added to any cabled MA300 system at any time.

The use of the MA300 Radio Telemetry option does not change the EMG system specifications in any way. All MA300 systems will maintain their fully frequency response and the overall performance of the system will be identical to that obtained using a cable with one exception. When using a cable, the signal path integrity between the backpack and the desktop unit is guaranteed but this is not the case with radio transmissions due to many factors such as signal strength, multi-path reflections, interference, and barriers between the transmitter and receiver that may interfere with radio frequency transmissions.

The MA300 radio-telemetry system attempts to deal with these problems by including error correcting and error check information with the transmitted data that allows the system to correct minor errors and detect major errors. As a result, when using a single radio telemetry transmitter and receiver, the CRC light (Cyclic Redundancy Check) on the Desk Top Unit (DTU) will almost certainly flash under most normal operating conditions. This is to be expected and in most cases when the transmitter and receiver are working correctly, and within a reasonable distance of each other, the system data will not be compromised.

The use of the MA300-RT radio telemetry option can be discontinued at any time and the subject backpack reconnected to the desk top unit via the standard 60 foot coaxial cable.

Transmitter

The telemetry unit contains a 2.4GHz ISM band radio transmitter and a battery to provide power to the subject backpack during EMG data collection.

The subject carried telemetry unit is lightweight and is easily carried by most subjects on the vest or belt supplied with your MA300 system. This unit includes a battery capable of powering both the radio transmitter and the subject backpack. The transmitter uses an internal antenna located in the center of the transmitter box and will work best if the transmitter pack is worn with the lights facing outwards towards the receiver although over short distances (less than twenty feet) this will not make a difference.



The transmitter battery should be charged before use to ensure maximum subject test time. Recharging the transmitter battery is easy as the MA300 Desk Top Unit

Just connect the BPU transmitter unit to the desktop unit via the coaxial cable to recharge the battery pack.

provides an ideal source of electrical power. To charge the transmitter battery just plug the transmitter unit into the coaxial cable connected to the desktop unit and the battery pack will start to charge.

Recharging the battery can be done at any time and the transmitter unit can be left attached overnight. The transmitter battery pack unit contains an intelligent battery charge management system and can not be over charged.

The transmitter backpack battery is a Lithium-Ion battery. It will take about six hours from completely dead to full charge but the battery can be recharged anytime - you do not have to wait for the battery to fully discharge before charging it. The running time for the transmitter and backpack will depend on the number of preamplifiers used - a sixteen channel system should run continuously for at least two and a half hours.

Transmitter Indicator Lights

The lights on the transmitter battery pack are Power/Signal Present (the bi-color LED), and three red lights indicating the levels of battery state. The power light will be red when the transmitter is switched on by pressing the on/off switch next to the coaxial connector and the backpack is disconnected - it will turn green when the backpack is power on, connected to the backpack and data is being transmitted. Regardless of the power switch, the transmitter is always disabled unless the backpack is connected.

The three battery status lights should always be on – the transmitter battery needs charging when only one or two lights are lit.

The radio telemetry receiver is powered directly by the DTU and does not need a separate power adaptor.

Receiver

The lights on the receiver are Power, and three levels of Received Signal Strength. The power light will be lit when the receiver is connected to the DTU. It is strongly recommended that the antenna is connected directly to the receiver although the link will work over short distances (less than twenty feet) without the antenna in most cases. An external high gain antenna can be connected if necessary to boost the range of the system outdoors but you will not need it in a lab. Simply placing the receiver (with antenna attached) so that it can be seen in the general lab area should be sufficient.

The ideal location for a single receiver in most gait labs is to place it at the side of the lab, opposite the mid-section of the subject walkway. This is easily accomplished in most situations since the receiver is normally plugged into the 60 foot coaxial cable and can be placed in any convenient position in the lab.

This location also makes it easy to disconnect the receiver and plug the transmitter battery pack into its place at the end of the coaxial cable to recharge the transmitter battery.



Using the Radio Telemetry System

Using the Radio Telemetry system is very simple. These instructions assume that you have a fully charged transmitter receiver unit that displays four red lights when the unit is turned on without the backpack connected. The MA300-RT option is designed to be used with a standard cabled MA300 system:

- Verify that the rotary eight position switches on the transmitter/battery unit and the receiver are set to the same position relative to the indicator lights on both units.
- Unplug the coaxial cable from the subject backpack and connect the receiver (with the antenna) to the coaxial cable in the place of the backpack unit. Initially the receiver power light will turn on but the three signal strength lights will not be lit. This indicates that the receiver is powered up and waiting to receive a signal from the backpack.
- Using the short coaxial cable supplied with the transmitter/battery pack, connect the receiver to the MA300 backpack and turn the unit on - the three red battery level lights on the transmitter/battery pack should turn on and the transmitter signal light will be green (it turns orange briefly during the power up sequence). The green power light on the subject backpack will also turn on, indicating that the battery pack is powering the MA300 backpack.
- Check the receiver, connect to the MA300 Desk Top Unit via the coaxial cable and verify that all the receiver lights are illuminated. This indicates that the receiver is powered up and getting a strong signal from the subject backpack and transmitter. The telemetry link is now working.

You will notice that when the telemetry link is in use the CRC light on the desktop will flash - this is normal and indicates that an error was detected in the received and decrypted data signal - however single CRC errors will be corrected and will not appear in the raw data.

The working distance for the system depends on many factors but, with reasonable receiver placement and the transmitter/battery pack worn on the subject belt or jacket, you can expect 50 to 100 feet with minimal signal dropout. This distance can be extended with the addition of a high gain antenna to the receiver or the addition of more receivers with an MA300-DR diversity receiver switch.

Radio Telemetry Quality

The radio telemetry link can be replaced by the coaxial cable at any time to guarantee signal quality.

With reasonable care, the quality of data available over the MA300-RT radio telemetry link will be identical to that available when using a cable however, unlike a cabled system, radio transmissions can be affected by many different forms of interference. You can monitor the MA300-RT radio telemetry transmission quality in a number of different ways:

1. All three of the receiver signal level lights should be on - if you are finding that you only have one or two of the three lights on then the receiver is not getting the best signal and should be repositioned so that the antenna can be seen by the subject. Also make sure that the lights on the transmitter/battery pack can be seen by someone standing by the receiver if at all possible.

2. Watch the CRC light on the desktop unit - this may flash intermittently unless the receiver and transmitter are very close but the CRC light only indicates that an error has been detected. The Desktop unit can correct many single CRC errors and so a CRC flash does necessarily not indicate a problem with the transmitted signal unless it is on continuously.
3. Whenever the internal logic detects one or more received signal errors the CRC output pin on the MA300 analog output connector will drop from logic one (approximately 4.5Volts) to logic zero or close to zero volts DC on the output pin. This pin can be recorded and monitored along with the EMG, footswitch and auxiliary channels to provide information about the received signal reliability.

Signal dropout problems can often be eliminated by adding additional receivers with the MA300-DR diversity system.

When uncorrectable transmission errors occur in the received signal the MA300 will hold its output levels steady until the received signal quality improves to the point that the MA300 data stream can be detected reliably. This will show up in the data as drop-out – periods where the received signal is a flat line rather than introducing bursts of “EMG” like noise into the detected signal.

Due to the high data sample rate of the EMG channels in all MA300 systems – compared to the lower data rates used by the footswitch and auxiliary channels, signal dropout will usually be seen in the footswitch and auxiliary data channels before any EMG signal dropout is observed.

RF Interference

It is always possible to use the MA300 system with a standard coaxial cable to completely avoid radio frequency interference problems and guarantee clean EMG signals.

There are many potential sources for interference for devices operating in the 2.4GHz ISM band and, depending on the location of the MA300-RT system, these may be sources of intermittent signal problems. In general, most interference problems can be solved by either repositioning the MA300-RT receiver or by adding the MA300-DR diversity option with additional receivers. Since the use of the 2.4GHz ISM band is unregulated, any interference problems must be resolved by repositioning the antennas or removing the interference sources.

Cordless Telephones

Many cordless telephones and baby monitors use the 2.4 GHz ISM frequency band which can cause interference to Wi-Fi devices but generally these devices will use frequencies at the lower end of the ISM band and will not interfere with the MA300-RT telemetry system.

Bluetooth Devices

The Bluetooth protocol is used in short-range communications with many computer accessories and modern cell phones. The Bluetooth protocol changes its operating frequency up to 1600 times per second but is generally very low power. Bluetooth devices that use Adaptive Frequency Hopping will normally detect an operating MA300-RT system and negotiating a communications channel list to avoid interfering with the MA300-RT transmissions.

Car alarms

Some car manufacturers use the 2.4 GHz ISB band for the internal movement sensors. Most car alarm sensors transmit at 2.45 GHz and while they may interfere with Wi-Fi communications using channels 8 and 9, they will not interfere with the MA300 system.

Microwave ovens

Microwave ovens operate by emitting a very high power signal in the 2.4 GHz band and rely on the internal shielding within the oven to suppress interference. Older microwave ovens with poor shielding may cause significant interference during operation and should be replaced as high power microwave radiation can be harmful.

Wireless Cameras and Video devices

Wireless cameras and video links normally transmit a continuous video signal over a short distance using a single frequency with the same transmitter power (10mW) as the MA300-RT telemetry system and may cause mutual interference. Interference problems can usually be resolved by operating either the MA300-RT system or the video transmission source on a different frequency. In general, obtaining a clean video picture without bars or shifting patterns while the MA300-RT system is operating will guarantee that the two devices are not interfering.

Wi-Fi networks

Wi-Fi networks operating in the 2.4GHz band will not normally interfere with the MA300-RT radio telemetry system. In general it should be possible to operate multiple Wi-Fi networks together with MA300-RT system in the same room without mutual interference.

ZigBee Networks

ZigBee wireless data networks operate in the 2.4GHz ISM band, and may be subject to interference from other devices such as the MA300-RT operating in that same band. ZigBee devices are usually very low power and generally work well with devices like the MA300-RT that use a single fixed transmission frequency.

Troubleshooting Telemetry Problems

There are four lights on the Telemetry receiver connected to the DTU. Looking at the receiver with the antenna pointing away from you, the light on the right side indicates that the receiver is ON. The other three lights indicate received signal strength - they will be all ON when the signal strength is good but you may see only one or two of the three signal strength lights on when the signal strength is lower.

If none of the three signal strength lights are on when the back-pack is close to the receiver then confirm that the receiver and transmitter are both using the same channel - the channel switch on both the receiver and the transmitter **MUST** be in the same position.

It's normal for the foot switch lights on the DTU to flash if the signal strength drops too low and the MA300 system is unable to correct transmission errors. This is likely when only one of the three signal strength indicators is lit. If possible reposition the receiver (connected to the DTU via the 60 foot coaxial cable) so that is closer to the subject and in direct line-of-sight of the subject.

The MA300 system deals with signal problems by checking each received data block. If an uncorrectable error is detected then the data block is dropped and the "Parity" signal line (CRC ERR on the front panel) is dropped (TTL "0") until a good data sequence is received. When a good data block is received the Parity line goes back up to TTL "1" and the CRC ERR light goes out. Single data drops are almost unnoticeable as this method prevents most minor errors appearing on the signal output - the only effect is that the total system frequency response of the EMG channels (normally 2kHz) is briefly lowered to 1kHz.

Most MA300 telemetry problems can be solved by adding additional receivers via the MA300-DR option. This can dramatically improve both the range and the reliability of the transmitted data.

Diversity Receiver Option

The initial decryption of the telemetry data stream is performed within each MA300-RX telemetry receiver to recreate the data packet generated by the MA300 backpack.

The MA300-DR diversity receiver switch allows data from multiple MA300-RX receivers to be combined to dramatically improve the reliability of the radio telemetry link. Using multiple receivers improves the probability that one of the receivers will receive a clean signal without errors. The function of the diversity system option is to ensure that the best signal will always be supplied to the DTU to provide the most reliable telemetry signal reception.

The real-time telemetry data stream sent from the MA300-TX telemetry transmitter includes an error checking code (a cyclic redundancy check or CRC) for each packet of data within the data stream. By examining the CRC value of each packet the MA300-DR diversity receiver switch can determine if each of the data packets within the data stream has been received correctly. Telemetry data corruption problems can be caused by many different problems including poor signal strength, external interference, and multi-path reflections.

When MA300 telemetry data packets are received, the MA300-DR diversity receiver switch checks the CRC of each packet from each receiver. The first telemetry packet that is received the correct CRC is immediately passed on to the DTU while "bad" data packets that fail the CRC error check are ignored. This error checking process is carried out in real-time for every packet at a rate of four-thousand packets per second and delays the real-time signal by only 250us.

Diversity Connections

The MA300-DR diversity receiver switch has three LEMO coaxial connectors on one end, supporting up to three MA300-RX receiver modules, and a single LEMO coaxial connector on the opposite end that should be connected to the DTU with a short LEMO cable. The MA300-DR diversity receiver switch is powered by the DTU and does not need any external power source.

Up to three MA300-RX receivers can be connected to the MA300-DR diversity receiver switch. While the MA300 system will function using a single receiver, at least two receivers must be connected to provide diversity reception. The receivers can be connected to any two of the three input connectors.

The MA300-DR diversity receiver switch is supplied with a 5m LEMO connector cable which should be used to connect the diversity system box to the DTU. The cables to the MA300-RX receivers can be up to 10m in length, allowing multiple receivers to be widely separated around the data collection area, producing a marked improvement in reduction of CRC errors and the related data drop out.

Diversity Indicators

Each of the diversity input channels has a set of three colored indicator lights associated with it. Since the data streams sampled by the MA300-DR are being processed in real time, the receiver indicator lights can switch at very high rates and the persistence of vision will often cause the various indicators to appear to light in contradictory manners. For example, when two or more data streams are less than 100% reliable, it is normal that all of the indicators for the associated channels may appear to be lit simultaneously. This is not an error as it demonstrates that the Diversity Receiver is functioning correctly, switching between multiple "unreliable" data streams in real-time to maintain a single reliable output data stream to the DTU.

The yellow receiver input LED is lit when the MA300-RX receiver connected to the channel is selected by the diversity switch and data from this channel is being presented to the DTU – this indicates the “active” receiver at any given instant.

The red receiver input LED is lit when data from the associated MA300-RX channel does not have the correct CRC. This will be the case when the channel does not have an MA300-RX receiver connected, or the connected receiver has supplied a bad CRC.

The green LED is lit when the associated channel data has an MA300-RX receiver connected and the data has a good CRC. The receiver lights are shown in the illustration below on the left side with the three associated MA300-RX receiver connections.

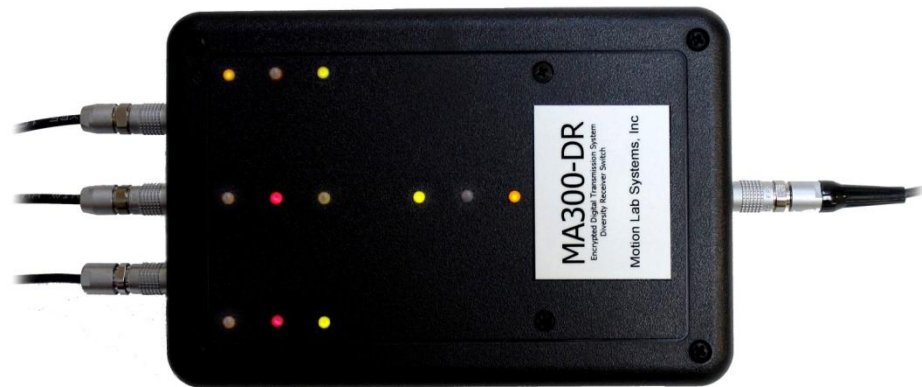


Figure 12 - An MA300-DR diversity receiver switch connected to three MA300-RX receivers.

In the illustration above, the upper set of lights indicates that this channel is selected (orange light) and has a good signal (green light). The middle set of lights indicates that this receiver is not picking up a signal, while the lower set of lights indicates that it's picking up some good data with bad data – both red and green lights appear to be lit simultaneously.

The MA300-DR diversity receiver switch also has three LED indicators for the DTU connector – shown on the right side of the illustration above. While the individual receiver lights will often change status very rapidly, the DTU output indicators should remain solidly lit. The green output LED lights when the output stream to the DTU is error free while the yellow LED indicates that the diversity system is connected to, and powered by, the DTU. The red LED will light when the data stream is either missing or contains CRC errors. Under normal operation, the green and orange status lights for the output stream will be always lit and the red light will only light if errors are detected – ideally, the red light should never be lit.

Errors in the DTU output stream can usually be eliminated in most laboratory configurations by placing up to three MA300-RX receivers in different locations around the data collection volume.

Safety

The connectors on the MA300-DR diversity receiver switch should only be connected to either the DTU or the wireless receivers. They should only be connected with cables supplied by Motion Lab Systems.

The cables can be a tripping hazard when extended across the floor so they should be taped down or mounted within cable tunnels.

Operational Tests

System Operation

When an MA300 system is first installed it is important to verify the functionality of the system so that the users will know that the data reported by the EMG systems is trustworthy. This next section describes a number of simple tests that should be performed by the person installing the system, and later by the users of the system, to demonstrate that the MA300 system is working and that the data from the system can be trusted and incorporated with other data inputs (forces, kinematics etc) as part of the overall data interpretation process. These tests should be performed on a regular basis depending on the system usage and any local accreditation requirements to ensure insuring accuracy and repeatability of the EMG system data. At a minimum we recommend that these tests are performed annually and whenever the overall system configuration is changed in any way that might affect the EMG data.

These tests describe a basic functional check that each EMG channel is working correctly and allow you to verify that each EMG signal is being record on the correct channel of your data acquisition or Motion Capture system. You will need to configure your data collection system so that you can visually monitor or observe both the individual EMG signals as well as view all of the supported EMG channels simultaneously. This is easy to do if you are using our MA720 (Dataq DI-720) data collection and real-time monitor, otherwise you will need to configure your Motion Capture or EMG data collection system so that you can view the EMG data.

Start with the MA300 system powered up and connected as normal for a subject test, then disconnect all of the preamplifiers from the backpack. This is an excellent time to perform basic cleaning of the preamplifiers and leads if this is not part of your daily maintenance. When cleaning the preamplifiers it is a good idea to inspect the leads for any signs of damage (nicks, cuts, exposed wires etc) that may cause problems in the future – most damaged preamplifiers can be repaired inexpensively by returning them to Motion Lab Systems, Inc.

Connect a preamplifier to the first EMG channel of the MA300 backpack and apply the preamplifier to a suitable muscle that you have good control over - the *Pollicis Brevis* muscles at the base of the thumb are a good choice in most people. Assuming that you can view the EMG data live, closely observe the EMG signal while you contract the muscle, and also while the muscle is quiescent. You should see a clean EMG signal while the muscle contracts and a relatively quiet baseline with the muscle relaxed – generally most people find it easy to generate a controlled EMG signal but the first few times that you perform this test you may have to work on relaxing the hand sufficiently to produce a flat baseline.

This test has two parts – initially you should be able to observe EMG activity in the channel and also a quiescent baseline with little EMG signal. If you see large

amounts to AC line noise at this point then you may need to provide additional grounding for the subject and check that they are not touching an ungrounded metal desk or other source of interference. If you can not get rid of the AC line noise then you may have a defective preamplifier (a CMRR problem). If you suspect this is the case then put the preamplifier to one side and repeat the test with another preamplifier until you find a combination that produces clean EMG data and flat baselines. This part of the test confirms that the preamplifier and MA300 system can produce a clean EMG signal on the expected channel.

The second part of this test is to check that the EMG signal that you have been monitoring appears in the expected channel and **ONLY** that channel. To check this simply continue generating a series of EMG contractions and examine **ALL** of the EMG channels that your MA300 system supports. The EMG contractions must not appear on any other channel than the channel that the preamplifier is connected to on the MA300 backpack. This test confirms that data from the channel appears on the correct channel of your data collection/monitoring system and only on that channel verifying that crosstalk (the appearance of data on a channel other than the channel that the preamplifier is connected to) does not occur.

When you are satisfied, remove the preamplifier from the backpack and place it to one side. You have verified the functionality of both the preamplifier and one channel of the EMG system.

Now connect another preamplifier to the next channel on the MA300 system and repeat the test once again verifying that the EMG signal appears in the expected channel and only that channel. Continue this test until you have tested all of the EMG channels, thus verifying that each of the EMG channels is functioning **AND** that the EMG data is appearing on the expected channel and **ONLY** on the expected channel.

On completion of these tests you can be confident that your MA300 system is performing correctly and that the EMG channels and individual preamplifiers are functional. You have also shown that the EMG channel assignments are correct and that an EMG signal applied to a channel can be located on the correct channel of your data collection system.

EMG signal reference

The relative gains across each channel on the MA300 system can be observed quite easily by disconnecting the preamplifiers from the MA300 and pressing the **Test** button at the bottom of the backpack. This applies an internally generated sine wave signal (equivalent to 156uV RMS at 78Hz) that is applied to each EMG channel input when this button is pressed. The observed amplitude of each EMG channel should vary in direct relation to the gain switch settings with higher gain switch settings producing larger signals and lower settings producing smaller signals.

It is important to note at this point that this feature does not “calibrate” the EMG system – it merely provides a reference level that allows the user to determine the relative gains applied to each EMG channel by the individual gain switch settings. The calculation is relatively simple- the overall gain applied to the EMG signal is:

$$20 \times V_{out}/V_{ref}$$

Where 20 is the preamplifier gain, V_{out} is the RMS value measured at the output of the MA300 and V_{ref} is the reference voltage – in this case 0.000000156 Volts RMS. Since each EMG channel has a separate gain switch this calculation can be tedious to perform on a regular basis so we have added the ability to automate the gain calculation as a feature of our EMG software. Both the **EMG Analysis** and the **EMG**

Graphing software packages support calculation of the individual EMG channel gains given a data file that has been created using the internal "test" signal.

You can use this feature to make a basic check that the individual channel gains controls on the MA300 backpack are functional if your data collection system supports the creation of EMG data files in either the Windaq or C3D file formats. Windaq is a file type created by the Dataq software used by the MA720/DI720 ADC, while C3D is a biomechanics file format supported by almost all major Motion Capture systems. The **EMG Analysis** (optional software application) and **EMG Graphing** software supplied with the MA300 supports both file formats.

To perform this test you must disconnect all of the preamplifiers from the backpack and make a recording (either C3D or WDQ format) across all of the EMG channels while the Test button is depressed, applying the signal to the EMG channels.

Open the recorded file using our EMG software, identify all of the EMG channels as "EMG" data and assign a side to each channel. This will display the recorded sine wave test signal and (depending on the configuration of the software) can display the peak to peak signal level on each channel. The actual signal level will vary depending on the individual channel gain settings but will be less than 5 Volts peak.

This data file can then be calibrated in one of two different ways - either by calibrating against itself (thus demonstrating that the software calibration function is correct) or by selecting the individual gain switch setting on each channel to demonstrate that the individual channel gain values selected by the backpack gain switches are correct). Both methods should provide identical results, effectively reporting the equivalent level of the "test" signal as 220uV peak (equivalent to 156uV RMS). These operations are described in detail in the EMG Tutorial Guide.

Hardware Calibration

The MA300 User Guide does not talk about *calibration* of the MA300 system because we do not market the EMG system as a device with what is called "*a measurement function*" - that is to say that we don't claim that the system has a specific accuracy, or that the amplitude of the system data is directly traceable to a National Standard.

Although we do not provide a "calibration certificate" with the system, the MA300 system does return EMG levels in terms of volts and does have ten gain settings on each channel. As described above, our software provides a method of translating the EMG signal levels produced by the MA300 and applied to an Analog Data Convertor (ADC) into EMG levels in terms on millivolts or microvolts at the skin surface.

If you wish to perform a calibration of the MA300 system then you will need two pieces of equipment:

- A signal source that produces a known differential signal level in millivolts at EMG frequencies (Medi Cal Instruments Model 220 Biomedical Function Generator or equivalent).
- A Digital AC voltmeter that can measure true RMS AC voltages (Fluke 45 or equivalent).

Calibration of the MA300 system is performed by applying a differential signal at a known level (typically 500uV RMS at 100Hz) to the input of a preamplifier connected the backpack and measuring the RMS AC output of the EMG system.

This measurement must be repeated 10 times for each EMG channels, once for each gain switch setting thus a 16 channel EMG system will require 160 individual measurements to verify the gain switch settings across all of the channels.

In addition, an additional 16 measurements could be made to check Common Mode Rejection of each preamplifier used by there system. This additional test does not measure any property of the MA300 but instead determines the Common Mode Rejection Ratio (CMRR) of the individual preamplifiers. The CMRR is tested by connecting both EMG inputs together and applying a large (1-2V AC at 70Hz) signal between the two preamplifier inputs and the preamplifier ground. This should result in a minimal output signal at the MA300 output connector.

A great deal of care is needed making both of these measurements if you are to avoid contaminating the results with external interference from AC power line noise. These are tests that have to be performed under controlled conditions to have any validity.

A quick test of the MA300 system can be performed by pressing the **Test** button at the bottom of the backpack and measuring the output from the DTU on each channel with the EMG gain control set to position 9, the maximum gain value. When correctly set up the backpack will generate a 78Hz sine wave with a peak to peak value of 8.0 volts $\pm 0.2V$ on the DTU output connector, equivalent to total gain, from x20 gain preamplifier input to the DTU analog output of 18000 $\pm 2\%$.

Test Procedures

Overview

The test procedures described in this chapter cover the basic tests needed to verify the correct operation of any MA300 system. These tests should only be performed by competent personnel who have read and understood these procedures and are familiar with the test equipment and test conditions required by these tests.

The following test equipment is required to perform these tests:

- Digital Multi Meter (DMM) capable of measuring DC volts, RMS AC Volts and Ohms.
- Dual Trace Oscilloscope with at least 100MHz bandwidth.
- A 10 MHz Frequency Counter with 1Hz resolution.
- A Signal Generator (10Hz to 10 kHz) with both single ended and differential outputs and an output range of 0-5V.
- Variable DC Power Supply with current limit 0-30Volts DC at 1Amp.
- Hipotronics HD103 Hi-Pot electrical test unit.
- A fully tested MA300-28 backpack (BPU) with standard MA133-60 cable.
- A fully tested MA300 deck top unit (DTU).

These test procedures assumes the operator is technically skilled to read and interpret schematics, and is trained on the use of the test set and basic electronic bench tools and equipment.

Desk Top Unit Tests

Initial Inspection

Using the DMM, perform the following resistance checks before connecting DC power to the main Desk Top Unit (DTU) circuit board to verify that the resistance is greater than 100 Ohms between the following test points:

- TP1 to TP2
- TP1 to TP3
- TP1 to TP4

- TP3 to TP4

Verify the following resistance measurements:

- P1-2 to TP1 ($\sim 10\text{M}\Omega$)
- E1 to TP1 ($\sim 1\text{k}\Omega$)

Power on Test

Using the variable DC Power Supply, apply 12 Volts DC to connector P3 (1, 2 = 0V; 3, 4 = +12V DC) and verify that the current draw is less than 600mA.

With the DMM ground on TP1, confirm that the following measurements are correct:

- TP2 = +5Volts DC $\pm 3\%$
- TP3 = +12 Volts DC $\pm 3\%$
- TP4 = -12 Volts DC $\pm 5\%$

Connecting the DTU to AC power may expose the technician to lethal AC voltage within the power supply section.

The DTU main circuit board may now be top assembled into the DTU case and the analog signal ribbon cable fitted between P4 and P5. The following tests are performed without a back pack unit connected. If you are performing an initial setup and test of the DTU then the two preset potentiometers (RV1 and RV2) should be set to their mid position.

- U5 pin 5 = 5.46 VDC $\pm 0.2\text{V}$ (threshold for SYNC1 pulse)
- U5 pin 3 = 5.88 VDC $\pm 0.2\text{V}$ (threshold for SYNC2 pulse)
- U19 pin 19 = 5.00 VDC $\pm 0.1\text{V}$ (analog DAC reference)
- TP12 = 0.00 VDC $\pm 0.1\text{V}$ (idle channel DAC output)
- TP13 = 0.00 VDC $\pm 0.05\text{V}$ (right event switch analog open value)
- TP14 = 0.00 VDC $\pm 0.05\text{V}$ (left event switch analog open value)
- U62 pin 12 = 0.00 VDC $\pm 0.02\text{V}$ (signal active detector with no signal)
- U56 pin 14 = 5.00 VDC $\pm 0.1\text{V}$ (event switch DAC reference)

Master DTU oscillator adjustment

Connect a shorting clip lead from TP5 to TP7 then connect the frequency counter using a coax to TP7 (gnd) and TP8 (hot 5V square wave) and adjust CV1 for 4.8000 MHz $\pm 50\text{Hz}$ to set the master oscillator frequency. Disconnect the clip lead from TP5 to TP7.

The frequency divider logic can now be checked by connecting the frequency counter to TP11 and confirm a 1000 Hz ($\pm 1\text{Hz}$) frequency is present.

Isolated Power Supply adjustment

Connect the DMM positive lead to P1-1 and the DMM ground to P1-2 and adjust RV1 for 12.0 VDC $\pm 0.1\text{V}$ to set the isolated power supply voltage.

Connect a known working and tested MA300-28 backpack to the DTU under test via a standard MA133-60 cable and verify that the DMM reads 12.0 VDC $\pm 0.2\text{V}$ to test the performance of the DTU isolated power supply under normal load conditions.

Sync adjustment and timing

Connect the oscilloscope to TP6 and set it to trigger on a positive going pulse of approximately 1 μ S and adjust RV2 for a 0.70 μ S $\pm$ 1 μ S pulse width.

Use one channel of the oscilloscope to verify the following signals with period errors of greater than 30% to be rejected:

- U9 pin 1: –ve 5V pulse (90nS wide bit sync)
- U16 pin 3: –ve 5V pulse (190nS wide, writes data to DAC latch)
- U10 pin 1: –ve 5V RC pulse (fast fall RC return, 200nS at midpoint)
- U11 pin 1: –ve 5V RC pulse (fast fall RC return, 0.6 to 1 μ S width)
- U24 pin 10: –ve 5V pulse (low periodicity 850nS pulse)
- Q2-2: +ve 5V RC pulse (fast rise, RC return 1.4 μ S wide at midpoint)

Finally, confirm that the search/lock time constant (R14, C10) by connecting the oscilloscope to U6 pin 6. This should be low with the backpack connected. Disconnect the backpack and confirm the RC rise of the signal with a 3.0V point at 10mS (50%) as the signal rises to 5 volts.

Event Switch Tests

The following test procedure verifies the correct operation of the DTU front panel indicators and additive encoding of the event switch analog outputs. This test may be performed with any mechanics event switches connected to any MA300 backpack that supports the event switch channels. MA300-X backpacks do not support separate event channels and cannot be used to perform these tests.

Separate tests must be performed for the Left and the Right event (footswitch) channels by closing each of the four event channels and noting the DTU front panel lights and measuring the Left and Right analog output channels.

- With FSW1 event channel closed and all other event channels open, confirm that only the front panel *TOE* indicator is lit and that the DMM reads 0.3125V $\pm$ 0.03V on the analog event output channel under test.
- With FSW2 event channel closed and all other event channels open, confirm that only the front panel *1ST* indicator is lit and that the DMM reads 0.625V $\pm$ 0.03V on the analog event output channel under test.
- With FSW3 event channel closed and all other event channels open, confirm that only the front panel *5TH* indicator is lit and that the DMM reads 1.25V $\pm$ 0.03V on the analog event output channel under test.
- With FSW4 event channel closed and all other event channels open, confirm that only the front panel *HEEL* indicator is lit and that the DMM reads 2.5V $\pm$ 0.03V on the analog event output channel under test.

Final DTU Test and Verification

Once the basic operation of the DTU has been confirmed the following tests may be performed to verify the DTU functionality. If this is the first time that the DTU has been assembled or if any service work has been performed on the DTU then the DTU should be powered up for a minimum of 24 hours to ensure temperature stability of the DTU and confirm the continued operation of the device. This power-on period is not required if the DTU is known to be fully functional.

The initial test condition is to power the DTU only from a properly grounded AC power supply without the backpack (BPU) connected. With the AC line power connected, and the DTU power switch on, confirm that the front panel indicators for the *Power*, *No.Sig*, and *C.R.C* are all illuminated. All eight Foot Switch indicators (*Toe*, *1ST*, *5TH*, and *Heel*) must be off.

At this point the Power On tests described earlier may be performed again to verify that the operating conditions of the DTU have not changed. This is recommended if this is the initial assembly test of the DTU but may be omitted during regular service operations.

EMG channel tests

Connect a known working and tested MA300-28 backpack to the DTU under test via a standard MA133-60 cable and set all of the EMG gain switches to 9 (maximum gain).

DC offset Test

Measure the DC offset on each of the 16 EMG channel analog outputs at the DB25 *Signal Output* connector on the rear of the DTU. Confirm that the DC offset on each channel is less than 0.02V.

Gain level Test

Noise Test

Press the BPU *TEST* button to apply the EMG channel test signal to the EMG inputs and verify that each analog output channel displays an 8V pk-pk sine wave $\pm 0.2V$ and confirm that the sine wave holds a steady voltage with the *TEST* button is pressed and the output returns to $0.0V \pm 0.2V$ when the button is released.

Crosstalk Test

EMG Bandwidth Test

With the BPU *TEST* button released and without any connections to the BPU input channels and all the EMG gain switches set to 9, confirm that the noise level on each EMG channel is less than 10mV pk-pk.

Signal Overload Test

Set all of the EMG gain switches to 0 and use the function generator to apply a 150mV sine wave at 100Hz to each EMG channel in turn while observing all remaining EMG channels to verify that the test signal appears on the applied channel and no other channel.

Perform this following test on each EMG channel with EMG gain switches set to 0 and the *Anti-Alias Bandwidth Filter* switch set to 0. Apply a sine wave at 200Hz and adjust the applied sine wave amplitude to obtain an 8 Volt pk-pk signal on the EMG channel output. Sweep the applied sine wave frequency to 2000Hz and observe the output signal amplitude smoothly decrease to 4 Volts $\pm 0.5V$.

Without changing the EMG gain switches or Anti-Alias Bandwidth Filter settings, increase the amplitude of the 200Hz sine wave applied to each channel in turn to 5.0V and check that overloading any EMG channel does not cause interference to any adjacent EMG channel.

Low Speed channel tests

The DTU supports four *LOW SPEED* or *Auxiliary* analog channels, each with a fixed gain of x1 and a signal bandwidth of DC to 150Hz. Each channel has an individual analog output pin assigned on the DB25 SIGNAL OUTPUT connector on the rear of the DTU.

Connect a known working and tested MA300-28 backpack to the DTU under test via a standard MA133-60 cable and verify that the output signals for the four *LOW SPEED* channels are all $0.0V \pm 0.02V$.

Use the function generator to apply a 3V square wave signal at 15Hz to each *LOW SPEED* channel in turn while observing the other three *LOW SPEED* channels to verify that the test signal appears on the applied channel and no other channel. The square wave signal should be flat and exhibit minimal undershoot and overshoot.

Increase the applied square wave frequency to 150Hz and verify that the channel displays a 1.5V pk-pk sine wave.

Electrical Isolation tests

Lethal Voltages are used in this test. EXTREME caution must be exercised.

Place the DTU on a non-conductive surface. The work area must be clean and clutter free, Ensure that there are no tools, equipment, components, loose wire or other conductive materials within two feet of the DTU and associated test equipment.

Verify that the Hipotronics HD103 POWER switch is off and that the voltage control knob is set to zero (fully counter clockwise) then make the following connections to the HD013.

- Connect the HD103 ground to the metal DTU case.
- Connect one of the two leads from the HD103 Hipot AC Output cable to the tip and case of the MA133 coaxial cable and connect the MA133 cable to the DTU. Ensure that the MA133 cable is neatly coiled and placed on the work surface at least six inches from the DTU case.
- Connect the second of the two leads from the HD103 Hipot AC Output cable to the neutral, live and ground pins of the AC power line plug and connect the AC line cord IEC connector to the DTU AC power input.
- Verify that the DTU AC power switch is ON during testing.

Do not touch the DTU or any of the cables connected to the DTU during the following Hi-pot test. Ensure that you can operate the HD103 without coming into contact with the DTU or anything connected to the DTU during the following steps.

With the Hi-Pot voltage control knob set to zero, turn the Hi-pot HD103 test set on and slowly but steadily turn the voltage control knob clockwise to increase the output voltage to 2,500 Volts AC.

Begin timing – it is normal for the DTU to make a slight cracking or buzzing sound during testing. Under no circumstances should you attempt to touch the DTU or any of the cables connected to the DTU during this test. Verify that the AC-DC milliamp meter on the HD103 reads less than 5 μ A and verify that the meter reading does not change while continuing testing for 60 seconds.

After 60 seconds have elapsed, reduce the voltage control knob to zero and return the HD103 power switch to the OFF position. Wait a few seconds to be certain that the test voltage is zero, and then disconnect all connections to the DTU. Switch off the DTU AC power switch.

Back Pack Unit Tests

This procedure tests the four BPU boards (MUX, GAIN, LEFT and RIGHT side panels) together as a set. One or more boards may be known good or all may be new and untested. Each LEFT or RIGHT side panel boards accepts up to 8 EMG channels, 2 LOW SPEED channels and 4 FOOTSWITCH or event switch channels. Different versions of the RIGHT and LEFT side panels exist to support various BPU models but all units use the same basic circuit board.

The BPU board set samples each EMG channel at a 5kHz sample rate and all other channels (LOW SPEED and FOOTSWITCH channels) at 1kHz rate. The EMG and LOW SPEED channels are digitized by a 12 bit ADC and integrated into a 1.2Mbs data stream. This data stream is sent as pulses over a coax connector and cable to the DTU while DC power received by the BPU from the DTU via the same coaxial cable.

Initial Inspection

The initial inspection at first assembly or service of the unit is performed with the individual MUX, GAIN, LEFT and RIGHT circuit boards removed from the BPU case and disconnected from each other.

- Confirm that the boards are clean
- Check that there are no solder splashes or unsoldered pins. Pay particular attention to the four-pin EMG input connectors on the RIGHT and LEFT side panels.
- Set all gain switches (S1-16) fitted to the GAIN board position 9.
- Set LPF switch (S17) on the GAIN board (if fitted) to position 0.

Power on Test of the MUX board

This test section is intended to perform basic functionality tests on the stand-alone MUX board before detailed testing and connection to the GAIN board. The MUX board is sitting on an insulated bench and tested in isolation.

- Set the external DC Power Supply to 9.0VDC ($\pm 5\%$) and a current limit of 400mA (± 50 mA).
- With the DC Supply OFF, connect clip leads from DC Supply to E1 and E2 of the MUX board. The negative lead is attached to E1 and the positive lead to E2.
- Use the DC DMM to measure between the MUX TP1 (Gnd) and TP2 (+5V) and confirm the current draw is 50mA ± 10 mA.

Operation at key test points is now checked with the DMM ground on TP1 to confirm the following DC measurements:

- TP2 = +5V $\pm 3\%$ (upper right of MUX board)
- TP1 = +5V $\pm 3\%$ (this is the analog positive supply)
- TP4 = -5V $\pm 5\%$ (this is the analog negative supply)

With one channel of the oscilloscope check waveforms below. Precise measurements are not warranted at this time as we are only checking basic functionality. The oscilloscope probe ground may be at TP1.

- TP5 = 9.6MHz 5V square wave at logic levels.
- TP6 = 5V negative logic pulse at 10 μ S intervals.
- TP7 = 5V negative logic pulse at 200 μ S intervals.
- TP8 = 5V negative logic pulse at 1mS intervals.
- TP9 = square wave logic signal at 133kHz (LPF output).

These next waveform checks require the use of a good scope and check key internal time constants. A sampling type scope is helpful for these signals.

- U20 pin 12 = short 5V +ve pulse, 300nS ± 100 nS wide with a 10 μ S period.
- U21 pin 11 = short 5V +ve pulse, 300nS ± 100 nS wide with a 1mS period.

Master Oscillator Adjustment

Connect the frequency counter using a coax cable to TP5 (hot +5V square wave) and the ground to TP1. Adjust CVI on the MUX board for 9.6MHz ± 50 Hz.

Place a spot of red QA lacquer on the edge of CVI to both stabilize and validate the adjustment.

Full board set tests

In this section, the GAIN board with LEFT and RIGHT side panels attached will be connected to the previously checked MUX board. DC power will be applied and then detailed channel by channel tests performed.

- Disconnect the DC +9V DC power supply from the MUX board.
- Connect the GAIN board to the MUX board using two FFC cables.
- Connect the two side panels using two FFC cables per board. The 24 position FFC cable is connected to the GAIN board and 6 position FFC cable to MUX board.

Normal assembly of the board set will use 50mm FFC cables but longer 150mm FFC cables are useful when working on the MUX board so that the MUX and GAIN boards can be clearly separated without risk of inadvertent short-circuits.

Power on Checks

Reconnect the +9V DC supply to the MUX board and confirm that the DC current drawn is 275mA $\pm$ 25mA.

Use the DC DMM to spot check DC supplies on the GAIN board as follows:

- C5 +ve = +3V $\pm$ 90mV (bottom left, +3V analog supply).
- C2 +ve = +5V $\pm$ 150mV (bottom center, digital +5V supply).
- C120 +ve = +3V $\pm$ 90mV (bottom right, +3V analog supply).
- C150 -ve = -3V $\pm$ 90mV (top left, -3V analog supply).
- C158 -ve = -3V $\pm$ 90mV (top right, -3V analog supply).

The following voltage checks are made at U59 (to the left of SW16 at the bottom center of the GAIN board):

- U59 pin 3 = +2.5V $\pm$ 100mV (signal overload positive reference).
- U59 pin 4 = -5V $\pm$ 150mV (digital negative supply).
- U59 pin 4 = -2.5V $\pm$ 100mV (signal overload negative reference).

Turn off the DC 9V power supply (connected to the MUX board) and disconnect from the DC power supply as we are now ready to set up the board set with the DTU system for full functionality tests.

Full DTU System Test Setup

Using a known functional and tested DTU, connect an MA133, 60 foot coaxial cable to the DTU (BPU INP) and the E1/E2 power connector on the BPU MUX board taking care to verify the polarity of the DC power connection to the MUX board.

Verify that the octal switch (SW17) is set to position to select 2 kHz low pass filtering of the EMG signal.

Verify that all the BCD switches fitted (SW1 through 16) to the GAIN board are set to position 9 to set the EMG channels to maximum gain.

Apply AC power to the DTU and confirm that the front panel indicators display shows the green *Power* indicator is ON, the orange *No. Sig.*, *CRC* and all eight green *Foot Switch* indicators are OFF.

Confirm that the BPU DC power indicator (Green LED lower right) is ON and the sixteen EMG signal overload indicators (Blue LEDs adjacent to the gain switches) are OFF.

BPU TEST signal Adjustment

The BPU generates a TEST signal which is simultaneously injected into each EMG channel when SW18 is pressed. The TEST signal output frequency is controlled by U33 on the MUX board and is a 78Hz sine wave. The signal amplitude is controlled by RVI on the MUX board. The signal amplitude will be adjusted on CH1 and then verified on all remaining channels.

- Verify that there is no connection to the Ch1 EMG input
- Press SW18 and observe the presence of a sine wave at 78Hz on channel 1 of the SIGNAL OUTPUT of the DTU.
- Adjust RV1 until channel 1 SIGNAL OUTPUT on the DTU reads 8.0Vpk-pk (2.83V RMS).
- Press and hold SW18 while observing the SIGNAL OUTPUT of the DTU for each of the EMG channels supported by the GAIN board and confirm that the TEST signal is between 2.70V RMS and 2.90V RMS at 78Hz for each channel.

Place a spot of red QA lacquer on the edge of RVI to both stabilize and validate the adjustment.

EMG Channel Performance Tests

This section of the procedure tests each of the EMG channels supported by the GAIN board and LEFT and RIGHT side panels for gain, frequency response, noise and cross-talk, as well as verifying the side panel connections. These tests are done repeatedly on each channel that is populated on the GAIN and side panels.

Connect a DMM to the EMG connector on channel 1 (all odd EMG channel numbers are on the LEFT side panel and all even EMG channel numbers are on the RIGHT side panel) between the +ve power pin and the -ve power pin on the EMG connector. Verify that the DMM reads 9.70 VDC ± 0.35 V.

Switch the DMM to measure current flow between the +ve power pin and the -ve power pin on the EMG connector. Verify that the DMM short circuit current flow reads < 50mA.

Set the function generator to generate a 150Hz sine wave at 3.08mV RMS (4.35mV peak) and connect it to EMG channel and confirm that the amplitude of channel 1 of the SIGNAL OUTPUT of the DTU is within specification per the following table for each Gain setting of the associated EMG channel GAIN switch (SW1 through 16 if fitted).

- Gain Switch Setting #9 = 2.89 – 2.94 Volts RMS
- Gain Switch Setting #8 = 2.60 – 2.66 Volts RMS
- Gain Switch Setting #7 = 2.03 – 2.08 Volts RMS
- Gain Switch Setting #6 = 1.78 – 1.82 Volts RMS
- Gain Switch Setting #5 = 1.47 – 1.51 Volts RMS

Verify the EMG input DC power supply.

Verify the EMG input DC current limit.

Verify the EMG gain switch values.

- Gain Switch Setting #4 = 1.22 – 1.26 Volts RMS
- Gain Switch Setting #3 = 0.88 – 0.92 Volts RMS
- Gain Switch Setting #2 = 0.63 – 0.67 Volts RMS
- Gain Switch Setting #1 = 0.31 – 0.35 Volts RMS
- Gain Switch Setting #0 = 0.07 – 0.09 Volts RMS

Verify the DC offsets for all EMG channels.

Verify EMG channel crosstalk performance.

Verify BPU low frequency performance.

Verify the BPU EMG frequency performance.

Verify the BPU mid-range performance and MA300-X bandwidth.

Verify the BPU high-range performance and MA300-X bandwidth cutoff.

Verify the EMG overload indicator performance.

Set all the Gain Switches to Position #4 and disconnect the function generator from the EMG inputs. Confirm that the DC offset of all 16 EMG channels at the SIGNAL OUTPUT of the DTU is less than 20mV.

With the function generator set to generate a 150Hz sine wave at 200mV and all gain switches on the GAIN board (SW1-16) set to minimum gain (Position #0), connect the test signal to each EMG channel in turn and confirm that signal applied to the GAIN board EMG channel appears in the correct EMG channel at the SIGNAL OUTPUT of the DTU. Note that the applied sine wave will be clipped. Use the DMM to confirm that the signal amplitude measured in each of the other EMG channels is less than 5mV.

The MA400 BPU has a low frequency response that includes DC and extends to 1kHz for the MA300-XII and MA300-XVI and 2kHz for all other GAIN boards. Set the function generator to generate a 20Hz sine wave at 154mV and use the DMM to confirm that the RMS reading for each EMG channel is 2.8V RMS $\pm 0.2V$.

Reset the function generator to generate a 200Hz sine wave at 154mV and use the DMM to confirm that the RMS reading for each EMG channel is 2.8V RMS $\pm 0.2V$.

Set the function generator to generate a 1000Hz sine wave at 154mV and use the DMM to confirm that the RMS reading for each EMG channel is 1.5V RMS $\pm 0.2V$ for MA300-X GAIN boards and 2.2V RMS $\pm 0.2V$ for all other GAIN boards.

Set the function generator to generate a 2000Hz sine wave at 154mV and use the DMM to confirm that the RMS reading for each EMG channel is < 15mV RMS for MA300-X GAIN boards and 1.0V RMS $\pm 0.2V$ for all other GAIN boards.

With the function generator set to generate a 150Hz sine wave, and all gain switches on the GAIN board (SW1-16) set to minimum gain (Position #0), slowly increase the applied sine wave amplitude until the BLUE overload indicator for the EMG channel under test illuminates. Confirm that the amplitude of the signal generator is 9.75V pk-pk $\pm 0.5V$ for each EMG channel under test and supported by the GAIN board.

Adjustable Low Pass Filter

The MA300-X GAIN boards do not support an adjustable low pass filter and this test should be omitted for MA300-X GAIN boards.

Verify the variable low pass filter performance for GAIN boards that include the LP filter option.

Each EMG channel on all other MA300 GAIN boards has switched capacitor low pass filter in each EMG channel. The filter cutoff frequency is determined by a clock signal generated by a small U33 (PIC16F84) which selects an appropriate clock frequency from an octal rotary switch on the GAIN board (SW17).

Set the function generator to generate a 150Hz sine wave on EMG channel 1 and adjust the amplitude for an 8.0Vpk-pk ($\pm 50mV$) on channel 1 of the SIGNAL OUTPUT of the DTU and set the LP filter control switch to position 7 (nominal 350Hz).

Increase the Function Generator frequency until the SIGNAL OUTPUT of the DTU falls from 8.0Vpk-pk to 4.0Vpk-pk ($\pm 5\%$). The frequency at which the output drops to 50% (-3dB) is shown below for each switch setting:

- #7 = -3dB at 377Hz $\pm$ 30Hz (nominal 350Hz).
- #6 = -3dB at 535Hz $\pm$ 35Hz (nominal 500Hz).
- #5 = -3dB at 800Hz $\pm$ 50Hz (nominal 750Hz).
- #4 = -3dB at 1030Hz $\pm$ 50Hz (nominal 1000Hz).
- #3 = -3dB at 1300Hz $\pm$ 50Hz (nominal 1250Hz).
- #2 = -3dB at 1480Hz $\pm$ 70Hz (nominal 1500Hz).
- #1 = -3dB at 1700Hz $\pm$ 90Hz (nominal 1750Hz).

Once a filter switch setting has been confirmed, select the next position for SW17 and increase the function generator frequency to verify the SIGNAL OUTPUT of the DTU falls from 8.0Vpk-pk to 4.0Vpk-pk ($\pm$ 5%) at the new frequency. Once the filter function has been verified for an EMG channel, reset the function generator and advance the test to the next EMG channel until all of the EMG channels supported by the GAIN board have been checked.

This completes the EMG channel tests.

Low Speed channel Performance Tests

All MA300 backpacks except the MA300-XVI support four *LOW SPEED* or *Auxiliary* analog channels, each with a fixed gain of x1 and a signal bandwidth of DC to 150Hz. Each channel (LOW A, B, C and D) has an individual analog output pin assigned on the DB25 SIGNAL OUTPUT connector on the rear of the DTU. Backpacks that support these channels have two connectors, each supplying +5V DC power and accepting two channels on the LEFT and RIGHT side panels. Channels A and C are accessible on the LEFT side panel, while channels B and D are on the RIGHT side panel. The following tests are performed on both the LEFT and RIGHT *LOW SPEED* connectors.

Confirm that the DC voltage between the LOW SPEED +ve pin and the ground pin is 5.0V ($\pm$ 0.25V) on both LEFT and RIGHT connectors.

Set the function generator for a 20Hz sine wave with an 8.0V pk-pk amplitude and apply this signal to each *LOW SPEED* channel input. Confirm that the SIGNAL OUTPUT of the DTU for each LOW SPEED channel is a clean sine wave of 8.0V ($\pm$ 0.25V) pk-pk.

Sweep the function generator frequency up until the DTU SIGNAL OUTPUT for the channel under test is -3dB at 4.0V ($\pm$ 0.25V) pk-pk and confirm that the frequency at which this occurs is 120Hz $\pm$ 10Hz.

Perform this test for each LOW SPEED channel and then disconnect the function generator from the LOW SPEED inputs.

Confirm that the baseline noise for each LOW SPEED channel is < 5mV and that the DC offset is less than 100mV.

Dedicated Foot Switch Input Tests

The MA300-X backpacks do not support dedicated foot switches and this inputs are not available on the LEFT and RIGHT side panels for this system. If the side panels do not have dedicated foot switch inputs then this procedure can be skipped.

Connect a 2k Ω resistor between the ground pin and the TOE input pin on the LEFT side panel *FOOTSWITCH* input pins on the 5-pin LEMO connector. Observe that the TOE indicator on the DTU illuminates.

Connect a 2k Ω resistor between the ground pin and the 1ST input pin on the LEFT side panel *FOOTSWITCH* input pins on the 5-pin LEMO connector. Observe that the 1ST indicator on the DTU illuminates.

Connect a 2k Ω resistor between the ground pin and the 5TH input pin on the LEFT side panel *FOOTSWITCH* input pins on the 5-pin LEMO connector. Observe that the 5TH indicator on the DTU illuminates.

Connect a 2k Ω resistor between the ground pin and the HEEL input pin on the LEFT side panel *FOOTSWITCH* input pins on the 5-pin LEMO connector. Observe that the HEEL indicator on the DTU illuminates.

Repeat this procedure with *FOOTSWITCH* input pins on the 5-pin LEMO connector on the RIGHT side panel.

System Latency

The system latency is measured in milliseconds and is the time that a signal is delayed by passing through the MA300 system. This delay is caused by the internal amplifiers and signal processing within the MA300 system electronics.

Set the function generator to generate a single, positive, pulse (one-shot mode) of 1mS duration at 200mV. Monitor the function generator signal with channel one of the oscilloscope and set the oscilloscope to trigger on the rising edge of the pulse. Apply the function generator signal to EMG channel 1 with the gain switch (SW1) set to “0” (minimum gain) – this is the input signal to the MA300 system.

Connect the second oscilloscope channel to the EMG channel 1 on the DB25 SIGNAL OUTPUT connector on the rear of the DTU. This will display the output signal from the pulse applied to the input of the MA300 system.

If the backpack has a variable low pass filter option then set the filter switch (SW17) to “0” for the maximum system bandwidth. MA300-X backpacks do not have a variable filter as they have a fixed 1000Hz bandwidth.

Trigger the function generator to generate a pulse and observe the two oscilloscope traces – you may need to adjust the time-base and channel gains to obtain a measurement. The interval between the two signals is the System Latency and will be < 2ms.

The maximum delay for MA300-18, 22 and 28 EMG systems is dependent of the Low Pass, Anti-Alias Filter switch (SW17) setting:

- 2000Hz = 1.2ms
- 1750Hz = 1.3ms
- 1500Hz = 1.4ms
- 1250Hz = 1.7ms
- 1000Hz = 1.9ms
- 750Hz = 2.4ms
- 500Hz = 3.2ms
- 350Hz = 4.4ms

Note that the MA300RT Radio Telemetry system does not introduce any additional delays.

Final Assembly

The boards are now ready for top assembly into a BPU case using production 50mm FFC connections. The following operations must be performed in sequence to fully assemble the backpack from its component parts.

1. Attach the shield to the bottom of the GAIN board using four 4-40 ¼ inch pan head screws.
2. Fit a 6 conductor, 50mm FFC to both PX3 and PX4 on the MUX board – these will connect to the LEFT and RIGHT side panels.
3. Fit a 24 conductor 50mm FFC to PX1 and a 10 conductor 50mm FFC to PX4 on the each end of the MUX board. These are the interconnections between the MUX and GAIN boards.
4. Carefully align the mounting posts on the MUX board with the mating holes on the GAIN board making sure that the boards are correctly aligned so that the 24 conductor and 10 conductor FFC connections can be connected after assembly. Press the GAIN board down onto the MUX board until the mounting posts fully engage the mating holes in the GAIN board.
5. Connect the two FFC connections between the GAIN and MUX boards and fit two 24 conductor 50mm FFC connections to PX1 and PX4 on the GAIN board.
6. Connect the twisted pair DC power cable from the chassis mounted coaxial LEMO connector to the MUX board, taking care to ensure that the +ve (RED) wire is connected to E2, adjacent to the SMT inductor. The –ve (BLACK) lead connects to the center connection marked E1.
7. Connect the TouchProof™ connector cable (GREEN) to E3 and press the MUX/GAIN board assembly onto the chassis mounted lugs. Make sure that the board assemble is pressed completely down to fully mate with the chassis mount fixings. The FFC connections can be folded under the MUX board as the board set is pressed into place.
8. The two side panels can be connected once the MUX/GAIN boards are mounted in the chassis. Connect the LEFT and RIGHT side panels using the 24 conductor and 6 conductor FFC connections.
9. Once all the boards are connected, each of the LEFT and RIGHT side panels can be attached to the base using two 4-40 ¼ inch flat head screws. At this point a power on test can be conducted with the TEST button pressed to verify that the boards are interconnected and fully functional. The cover can then be attached using four 4-40 ¼ inch flat head screws.

EMG Preamplifier Testing

Motion Lab Systems make a range of preamplifiers that share a common set of characteristics and identical electrical specifications for use with the MA300 EMG system. These preamplifiers differ in their physical appearance but all perform identically and many of their operational characteristics can be verified using a fully tested, functional MA300 system.

Input Impedance

The input impedance of the preamplifier is greater than 100,000,000 Ω and, as a result, it cannot be directly measured without specialized test equipment. Most Digital Multi-Meters (DMM) will not measure resistance greater than 10M Ω and

when used to measure the input impedance of a preamplifier they will report “open circuit” which, since the preamplifier input impedance is at least an order of magnitude greater than the range of the DMM, is correct. This measurement demonstrates that the preamplifier input impedance is greater than the maximum measurement that the instrument is capable of making.

The preamplifier has input overload protection circuitry which requires that any input impedance measurement is performed with a low voltage thus preventing the use of common mega ohmmeters that use high voltages to measure high resistances. Since the preamplifier integrated circuit is directly connected to the preamplifier inputs, a standard DMM measurement condition of “open circuit” demonstrates that the preamplifier has not failed in a low-impedance condition and should be accepted.

Input Noise

Precise measurement of the input noise of the preamplifier requires specialized equipment operated in a shielded room to eliminate background interference but an estimate of the noise level can be obtained via the following method.

Connect the DMM to the DB25 SIGNAL OUTPUT connector on the DTU at EMG channel 1 and set the BPU gain for EMG channel 1 (SW1) to the maximum value (switch position 9). Measure the background noise using the DMM set to measure RMS volts. This measurement is the total background noise of the MA300 system, the connections to the system and the DMM and will be subtracted from the measurement made with a preamplifier connected.

Connect the preamplifier under test to EMG channel 1, taking particular care to ensure that the all external noise source are removed from the test bench and that the inputs to the preamplifier are both connected to the backpack ground lead to prevent external noise from distorting the measurement. Record the DMM measurement of the preamplifier noise in RMS volts and subtract the baseline noise measurement of the system and test equipment from the DMM value. Divide the result by the total gain of the system (x18000) to obtain an estimate of the preamplifier input noise. In the following example, the baseline noise measurement of the system is 0.016V RMS which increases to 0.04V RMS when the preamplifier is connected:

$$\frac{0.040V - 0.016V}{18000} = 0.00000133V = 1.3\mu VRMS$$

This measurement requires precise measurement of exceptionally low voltages in the absence of external noise and interference and any external noise sources will raise the measured noise.

Common Mode Rejection Ratio

The Common Mode Rejection Ratio (CMRR) measures the ability of the preamplifier to reject signals that are common to both preamplifier inputs while amplifying signals that are different on each of the inputs. This is the basic mode of operation for a differential amplifier.

The CMRR is defined as the ratio of the powers of the differential gain over the common-mode gain, measured in positive decibels at a specified frequency which for the MA300 preamplifier can be written:

$$CMRR = 20 * \log_{10} \left(\frac{G_d}{G_c} \right) dB$$

Where G_d is the differential gain and G_c is the common mode gain. A precise measurement of the CMRR of the preamplifier requires specialized equipment

operated in a shielded room to eliminate background interference but an estimate of the CMRR can be obtained via the following method:

Connect the DMM to the DB25 SIGNAL OUTPUT connector on the DTU at EMG channel 1 and set the BPU gain for EMG channel 1 (SW1) to the minimum value (switch position 0) which is equivalent to a differential gain of x350 for the preamplifier and system under test.

Connect the preamplifier for the CMRR test to EMG channel 1, taking particular care to ensure that the all external noise source are removed from the test bench.

Set the function generator to output a frequency of 40Hz at 1.5V RMS and connect signal output of the function generator to both preamplifier inputs while the signal ground connection is connected to the preamplifier ground. If the preamplifier does not have a ground connection then the TouchProof™ ground connection on the backpack may be used.

Turn the power to the function generator off and record the DMM measurement of the preamplifier noise in RMS volts at the DB25 SIGNAL OUTPUT connector on the DTU. This establishes a baseline noise measurement of the system and test equipment. This measurement is the total background noise of the MA300 system, the connections to the system and the DMM and will be subtracted from the CMRR measurement in an effort to exclude noise as a factor in the CMRR measurement.

Turn the function generator on and record the DMM measurement at the DB25 SIGNAL OUTPUT connector on the DTU with 1.5V RMS applied to both preamplifier inputs with reference to the preamplifier ground connection. This is the applied common mode signal. In the following example, the baseline noise measurement of the system is 0.009V RMS and the common mode gain test result is 0.012V RMS. Thus the common mode gain of the preamplifiers is:

$$G_c = \frac{(0.012 - 0.009)}{1.5} = 0.002$$

Using this value in the CMRR calculation gives the result:

$$CMRR = 20 * \log_{10} \left(\frac{350}{0.002} \right) = 105 \text{ dB}$$

Field measurements of the CMRR value will always be lower than the theoretical CMRR value due to external noise, and unbalanced external factors including resistive leakage and lead capacitance.

Gain

Connect the preamplifier under test to EMG channel 1 on the backpack and set the gain control (SW1) to the “0” position for minimum EMG channel gain from the MA300 system. The quoted gain of the EMG system with SW1 set to “0” is x350 which includes the preamplifier gain – the gain of the backpack and DTU alone at this switch setting is x17.5 (350/20).

Connect the DMM to the EMG channel 1 output pin on the DB25 SIGNAL OUTPUT connector on the DTU and set it to read RMS volts.

Connect the preamplifier ground lead to the function generator ground and connect a lead from the backpack TouchProof™ ground connection to the function generator signal ground.

Set the function generator to differential output mode, select an output sine wave of 180Hz at 0.010V RMS, and connect the preamplifier signal input leads to the differential output signal from the function generator.

Use the DMM to measure the RMS voltage on EMG channel one. The gain of the preamplifier will be:

$$G = \frac{\left(\frac{V_{out}}{17.5}\right)}{V_{in}}$$

It's important to note that this calculated gain will be absolutely accurate as the calculated gain figure includes the gain of the MA300 backpack and DTU. More precise gain measurements for the preamplifier require that the preamplifier is tested in isolation from the MA300 BPU/DTU components.

Input Protection

The preamplifier contains overload protection circuitry to prevent damage to the device from the voltages generated during Nerve or Muscle Stimulation. This is easy to test by connecting an oscilloscope to observe the EMG channel output while a series of Nerve Stimulation pulses are applied to the preamplifier inputs. A typical nerve stimulator generates a series of current limited pulses of 200uS duration with instantaneous voltages of 60-100Volts peak.

The Input Protection may be tested using the same test set up as the Gain test by detaching the function generator from the preamplifier inputs and applying an active Nerve Stimulator pulse train to the preamplifier inputs. The EMG channel output signal will be disrupted while the Nerve Stimulator is applied to the preamplifier inputs. Turn the Nerve Stimulator off and disconnect it from the preamplifier. Reconnect the function generator and observe that the 180Hz sine wave is present on the DTU signal output.

Bandwidth

Precise measurement of the full bandwidth of the Motion Lap Systems EMG preamplifiers requires that the device is tested independently of the MA300 system because the upper range of the EMG preamplifier is greater than the range of the MA300 system. This is a design feature that ensures that the high frequency bandwidth of the MA300 system is independent of the preamplifier used while allowing the preamplifier to define the low frequency bandwidth of the system.

Connect an MA300-18, 22, or 28 backpack to the DTU and set the backpack anti-alias filter (SW17) to "0" to select the maximum EMG signal bandwidth. Connect the preamplifier under test to EMG channel 1 on the backpack and set the gain control (SW1) to the "0" position for minimum EMG channel gain from the MA300 system.

Connect the DMM to the EMG channel 1 output pin on the DB25 SIGNAL OUTPUT connector on the DTU and set it to read RMS volts.

Connect the preamplifier ground lead to the function generator ground and connect a lead from the backpack TouchProof™ ground connection to the function generator signal ground.

Set the function generator to differential output mode, select an output sine wave of 180Hz and connect the two preamplifier signal input leads to the differential output signals from the function generator.

Adjust the function generator amplitude so that the DMM, connected to EMG channel 1 output pin on the DB25 SIGNAL OUTPUT connector on the DTU, reads 1V RMS.

Decrease the function generator frequency until the DMM reads 0.5V RMS and note the frequency – this is the low frequency -3dB value. Increasing the function generator frequency until the DMM reads 0.5V RMS will document the high frequency -3dB point for the MA300 EMG system since the preamplifier frequency range is greater than the MA300 system.

Accurate measurement of the specifications requires a TEMPEST level test environment, fully shielded from external electromagnetic fields and electrical interference with filtered and isolated electrical power. In addition precise measurements of the preamplifier require that it is tested in isolation from the MA300 system with measurements at the preamplifier connector.

Connections

Signal Connections

Each MA300 EMG system is supplied with an analog output cable. This is normally a 1.5m shielded multi-core cable with a female DB-25 connector on one end and free wires on the other end – the wire ends are terminated in gold pins suitable for connection to many common types of analog input patch-panel. Longer cables are available on request, as are cables with BNC termination. Please contact Motion Lab Systems at the time of installation for a replacement analog interface cable if the cable supplied with your system is not suitable.

Important Warning

In order to maintain the electrical protections built into the MA300, it is important that all accessory equipment connected to the analog and digital interfaces of the MA300 meets the required safety standards. Thus any accessory equipment must be certified according to the respective IEC standards (i.e. IEC 950 for data processing equipment and IEC 601-1 for medical equipment). Furthermore, all configurations shall comply with the system standard IEC 601-1-1.

This means that everybody who connects additional equipment to the signal input connectors (MA300 backpack) or signal output connectors (DB-25 analog output connector or DB-9 digital output connector) is configuring a medical system, and is therefore responsible that the system complies with the requirements of IEC 601-1-1. If in doubt, you should consult your technical services department or your local representative.

The electrically isolated interface provided by the MA300 desktop system isolates the DTU interface from the subject backpack and provides essential safety isolation between the MA300 signal connections and the subject.

Male DB-25 connector

These are arranged to enable the user to connect quickly to the MA300 system. Pin connections for the DB-25 analog signals (SIGNAL OUT connector) are listed by pin number. If you are using flat ribbon cable to connect to the MA300 (not recommended) then please note that the connector pin number is NOT the same as the flat cable wire order. Pin #1 is at the top left hand side of the connector as viewed from the rear of the MA300. All analog output levels are ± 5 volts and include ESD protection.

The connections shown will vary depending on the number of channels that your system supports - unused channels will generally be at or close to ground potentials

but must not be used as additional grounds as this may generate noise in the signal outputs.

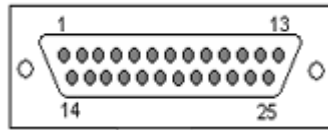


Figure 13 - Male DB-25 Analog Output connector

- 1 EMG channel 1
- 2 EMG channel 2
- 3 EMG channel 3
- 4 EMG channel 4
- 5 EMG channel 5
- 6 EMG channel 6
- 7 EMG channel 7
- 8 EMG channel 8
- 9 EMG channel 9
- 10 EMG channel 10
- 11 EMG channel 11
- 12 EMG channel 12
- 13 EMG channel 13
- 14 EMG channel 14
- 15 EMG channel 15
- 16 EMG channel 16
- 17 Analog Signal Return
- 18 Analog event switch - Left (0 to +4.688 volts)
- 19 Analog event switch - Right (0 to +4.688 volts)
- 20 Data parity (TTL High if Data is valid - normally not used)
- 21 Low speed channel A (DC-120 Hz channel)
- 22 Low speed channel B (DC-120 Hz channel)
- 23 Low speed channel C (DC-120 Hz channel)
- 24 Low speed channel D (DC-120 Hz channel)
- 25 Case (Chassis Ground - connect as appropriate)

These signals are generally self-explanatory, note that the data parity signal (pin 20) is not generally required and should not be connected to your data collection system. The case/chassis ground (AC line ground) is usually not connected unless you have ground loop problems – under these circumstances some careful investigation of the available ground sources may be required.

Female DB-9 connector

The MA300 does not require any connection to the DISPLAY connector in order to function. If present, this connector is provided for system testing and should not be used.

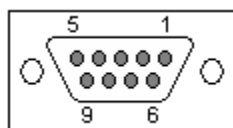


Figure 14 - Female DB-9 display connector

When present, the 9-pin display connector on the rear of the MA300 contains the following signals. This information is provided for technical use only.

- 1 Chassis Ground
- 2 Buffered BD1
- 3 Buffered WE1
- 4 Buffered FC1
- 5 Signal Ground
- 6 Reserved
- 7 Analog Ground
- 8 Fused +12 Volt DC
- 9 Buffered SIG

MA300 EMG Input Connector (Backpack)

Each MA300 EMG input channel connectors uses a four-pin LEMO or BINDER connector that supply DC power to the EMG pre-amplifier electrode and receives the amplified EMG signal.



Figure 15 - LEMO connector

The power supplied to each EMG input connector is protected from any possible short-circuit overload via a 100 ohm resistor in each power rail which provides current limiting, preventing the backpack from delivering more than 50mA through each power supply lead.

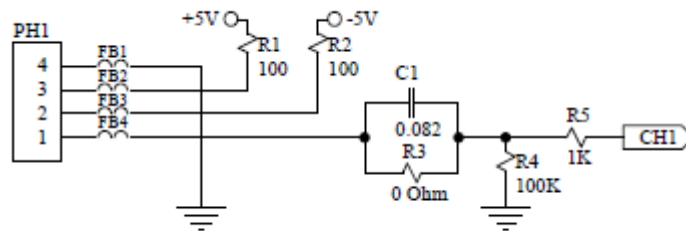
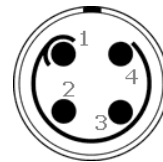


Figure 16 - EMG input schematic

LEMO pin connections

- 1 EMG signal
- 2 - 5Volt
- 3 +5 Volt
- 4 Analog Ground



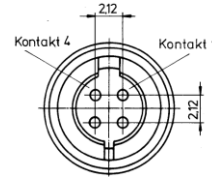
The pin connections and numbering scheme for the LEMO connectors is shown above looking into the plug connector – note that the pin order is identical for both LEMO and BINDER connectors but LEMO connectors are numbered counter clockwise, while BINDER connectors are numbered in the opposite direction.



Figure 17 - BINDER connector

BINDER pin connections

- 1 Analog Ground
- 2 +5 Volt
- 3 -5 Volt
- 4 EMG signal



ESD protection is provided within the external, active EMG pre-amplifiers supplied with the MA300 system. If you use non-MLS supplied devices with the MA300 backpack then be aware that other manufacturers devices may not provide the desired level of EMI, EMC and ESD protection.

MA300 Dedicated Event Switch Connector

The dedicated event switch inputs on some MA300 systems use a larger 5-pin LEMO connector than the EMG inputs (see [Figure 3](#)). Each event switch input is pulled to +5V via a 10k ohm resistor; pressure on the event switch to the switch common pin pulls the input to ground to indicate switch closure.



Figure 18 - Event switch LEMO connector

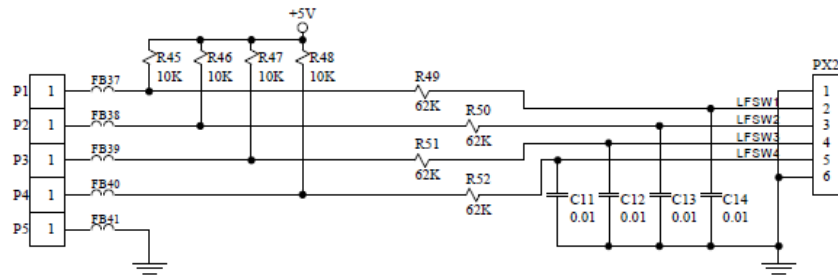
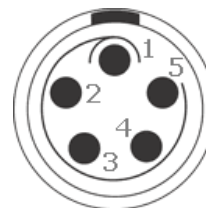


Figure 19 - Dedicated event input schematic

Dedicated Event connections

- 1 Switch #1 (toe)
- 2 Switch #2 (1st)
- 3 Switch #3 (5th)
- 4 Switch #4 (heel)
- 5 Switch Common



Each event switch input is conditioned and filtered to avoid problems with switch bounce and external interference. Connections to the event switch inputs can be made using the MA335 event switch cable.

MA300 Auxiliary Research Connector

The auxiliary connector (if fitted) is next to the event connector or at the lower end of the side panels. Most MA300 systems have two connectors, one on each side of the backpack – each connector provides two additional analog channels together with access to isolated DC power. These auxiliary channels have a bandwidth from DC to 120Hz and are suitable for event switch, goniometers or other low data rate devices. This auxiliary connector is not available on the MA300-XVI system.

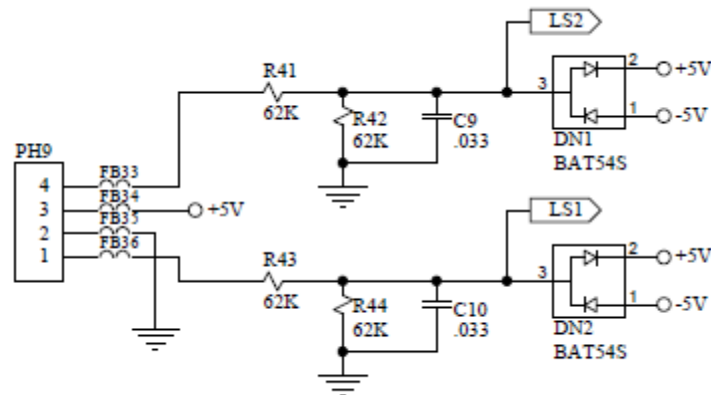
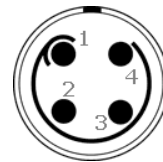


Figure 20 - Aux input schematic

LEMO auxiliary connections

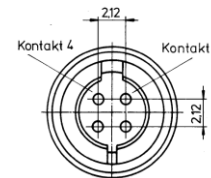
- 1 Inputs A & C
- 2 Common Ground
- 3 +5 Volt DC
- 4 Inputs B & D



Please contact technical support at Motion Lab Systems if you are in any doubt about connecting external interface circuitry to your MA300 system.

BINDER auxiliary connections

- 1 Inputs B & D
- 2 +5 Volt DC
- 3 Common Ground
- 4 Inputs A & C



Inputs to all four channels must be in the range of ± 2.5 Volts maximum. A small amount of isolated DC power may be drawn from the subject backpack to power any external interface circuitry. This power is drawn directly from the backpack power supply and care must be taken to avoid excessive current drain when constructing any external interface circuitry.

EMG signal filters

MA300 systems with a fixed 1kHz bandwidth will need a minimum 2kHz sample rate.

MA300 systems with a variable low pass filter can use a range of sample rates from 700Hz to greater than 4kHz depending on the data sampling system used.

Some MA300 systems contain a variable built-in Low Pass Filter in each EMG channel to define the analog EMG signal bandwidth before recording. The correct usage of these filters (where fitted) will enhance the quality of your recorded data by eliminating artifact caused when components of the incoming EMG signal exceed the ADC sampling limits. Even small amounts of high frequency noise, present in the ADC input signal, can cause significant amounts of artifact to appear in the sampled EMG recordings.

MA300 systems without a variable low pass filter have a single high quality, fixed, ten-pole low pass Bessel filter set to 1000 Hz -3dB across all EMG channels. If you are using a system with a fixed response then we recommend that you set your ADC sample rate to at least 2000 sample per second per channel or higher.

In addition, an optional band pass filter is also available that can provide high pass filtering to remove most forms of motion artifact if desired.

Variable Low Pass Filter

Some MA300 systems feature a variable ten-pole low pass Bessel filter controlled by a rotary switch on the subject backpack unit. This low pass filter applies to all of the EMG channels. The default bandwidth of the EMG channels on these MA300 systems is DC to 2,000 Hz making it suitable for most situations in EMG research and clinical use. The low end of this bandwidth is set by the EMG preamplifier while the high end of the bandwidth is controlled by the variable anti-alias filter.

Anti-Alias Filter settings (if available).		Analog Sampling Frequency	
		50 Hz Video Frame Rate	60 Hz Video Frame Rate
7	350 Hz.	800 (x16)	960 (x16)
6	500 Hz.	1000 (x20)	1200 (x20)
5	750 Hz.	1600 (x32)	1500 (x25)
4	1000 Hz.	2000 (x40)	2400 (x40)
3	1250 Hz.	2500 (x50)	3000 (x50)
2	1500 Hz.	3000 (x60)	3000 (x50)
1	1750 Hz.	3500 (x70)	3600 (x60)
0	2000 Hz.	4000 (x80)	4200 (x70)

Although the EMG system can reproduce EMG signals up to 2000 Hz, many data recording systems either cannot record frequencies this high or do not need this bandwidth. For example, surface EMG signals rarely exceed 350 Hz so if you are only making surface EMG recordings a bandwidth of 500 to 750 Hz is perfectly adequate.

However fine-wire EMG signals can easily exceed 1000Hz and, while it is unlikely that you will see significant EMG information above this frequency, it is certain that you will lose EMG information if your system bandwidth cannot handle these signals. Therefore the variable low pass filter included in some MA300 systems allows you to optimize your EMG bandwidth for the type of EMG signals that you are recording.

Almost all data collection systems will sample the incoming EMG signals at a fixed rate called the sample rate. You need to know what your analog sample rate is before

you can select the optimum MA300 variable Low Pass Filter settings. You should select a Low Pass Filter setting that is no more than half the data collection system sample rate.

For example, if you are collecting data via an ADC synchronized to a 60-Hz video system and the ADC is sampling the EMG signal 25 times per video frame then you will have an actual analog data sample rate of 1500 samples per second. You should select an Anti-Alias Filter setting of 750Hz (switch setting #5) in this case:

$$\frac{60 \text{ frames} \times 25 \text{ samples}}{2} = 750 \text{ Hz}$$

Being conservative when selecting a Low Pass Filter setting is usually best since spurious *signal aliasing* (also called Nyquist sampling errors) can occur if the incoming EMG signal changes faster than the data collection system can record it. Selecting the optimum Low Pass Filter setting may involve adjusting your analog data collection rate since the two items are interrelated.

High Pass filter option

All MA300 systems can be fitted with an optional high pass filter (part number MA300-F), which is controlled by a rotary switch on the back of the desktop unit.

Selecting a setting for the High Pass Filter is easier than selecting a Low Pass Filter setting since the principal function of the High Pass Filter is to remove unwanted low frequency artifact from the EMG signal before recording. Unless a High Pass Filter is installed, the EMG bandwidth will only be limited by the preamplifier used on each channel and thus all signals, whether they are EMG or not, will be recorded up to the low pass bandwidth limit set in the backpack. Fitting a high pass filter gives the user the ability to selectively limit the low frequencies in the EMG signal. While the ISEK standard and many researchers need EMG signals down to 10Hz or lower, the recommended high pass settings for gait analysis are between 40 Hz and 60 Hz to eliminate motion artifact from the recorded signals.

In addition to the high pass filter, the optional MA300-F filter card incorporates an additional low pass anti-aliasing filter that can be preset via an internal DIP switch to a range of different roll-off points listed in Appendix B.

This filter should be set depending on the maximum sampling or measuring rate of your analog recording or measuring system. Note that this optional filter allows the installer to limit the high-end bandwidth of the MA300 system regardless of the setting of the subject backpack filter.

Appendix A

Analog event switch levels

Replacement event switch sensors are available from Motion Lab Systems, Inc., or from your local distributor.

The MA300 is designed to use the event switch sensors supplied with the system. While you are free to use other types of switch sensors you should be aware that other switches or sensors may not give the same performance as those supplied by Motion Lab Systems, Inc. While every effort has been made to ensure that the MA300 event switch sensors are reliable, they have a limited lifetime in normal experimental use.

Dedicated event switch channels

Dedicated event switch data channels are designed specifically for event switch inputs and produce cleaner and more reliable event detection than using the auxiliary or EMG data channels.

MA300 systems that all support dedicated event switch channels enable the researcher to maximize their use of the EMG data channels. Each set of four event switches (nominally 'left' and 'right') on these system are encoded onto a single analog channel to allow all eight switch closures to be recorded using only two analog channels. By weighting each switch closure with a unique DC voltage, the results of switch closures can be arithmetically summed. The result is that each of the two analog event switch channels can have, at any given instant in time one of 16 unique DC values that indicate the state of all four switches.

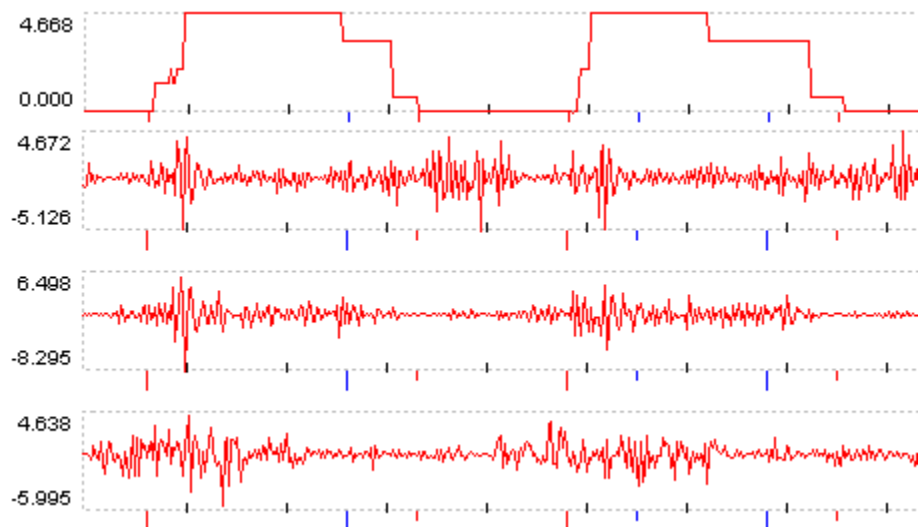


Figure 21 – MA300 event switch and EMG signals in normal gait

All sixteen possible values are listed in [Table 1](#) where "Switch #1" refers to the connection marked with a red dot on the event switch connecting cable. The

maximum DC output level of each channel is set to be a maximum of 4.688 volts when all four event switches are closed.

When combined with EMG recordings the resulting event switch signals are quite easy to interpret, enabling the analyst to easily determine the gait cycle phases of stance and swing.

While the discussion here is specific to clinical gait analysis, the event switch inputs are not limited to recording event switches and can be used for any switch recording needs, especially those that might require complete subject electrical isolation as the event switch signals have the same electrical isolation specifications as the EMG channels.

Default Analog Event Switch Output Voltages for the MA300				
Switch #1 (Toe)	Switch #2 (1st)	Switch #3 (5th)	Switch #4 (Heel)	Output Volts
0.000	0.000	0.000	0.000	0.000
0.3125	0.000	0.000	0.000	0.313
0.000	0.625	0.000	0.000	0.625
0.3125	0.625	0.000	0.000	0.938
0.000	0.000	1.250	0.000	1.250
0.3125	0.000	1.250	0.000	1.563
0.000	0.625	1.250	0.000	1.875
0.3125	0.625	1.250	0.000	2.188
0.000	0.000	0.000	2.500	2.500
0.3125	0.000	0.000	2.500	2.813
0.000	0.625	0.000	2.500	3.125
0.3125	0.625	0.000	2.500	3.438
0.000	0.000	1.250	2.500	3.750
0.3125	0.000	1.250	2.500	4.063
0.000	0.625	1.250	2.500	4.375
0.3125	0.625	1.250	2.500	4.688

Table 1 - Analog event switch levels

Alternative MA300 event channels

MA300 systems that lack the dedicated event switch channels can store event switch information by connecting an event switch with an adaptor cable to either an unused EMG data channel or one of the auxiliary data channels available on many MA300 systems.

In each case, each event switch signals will be recorded on its own analog channel as a positive pulse when the switch is closed. Thus two event switches on each foot (heel and toe to detect the stance and swing phases of gait) will require four analog channels.

Appendix B

Upgrading the MA300

Only technically qualified personnel should attempt to repair or customize an MA300 EMG system.

The MA300 is a digital EMG system and has been designed to be completely self-contained system with an absolute minimum of user adjustments and settings. The only adjustment that is normally necessary is to set the low pass filter to match the sampling rate of your data collection system. Individual EMG channel gains may be adjusted for optimum recording levels.

Most MA300 systems can be upgraded to add additional channels by exchanging the system backpack or returning the backpack to Motion Lab Systems for modification and installation of additional EMG channels. Please contact Motion Lab Systems or your distributor if you are interested in upgrading your system to add additional EMG channels. All MA300 systems may be fitted with an optional band-pass filter.

If you are in any doubt as to your ability to repair or modify the MA300 EMG system, or one of its options, then you should return the unit to Motion Lab Systems, Inc, or their agents and request them to perform the required operations for you as the MA300 is a patient connected device.

Service Contracts are available from Motion Lab Systems to provide full support of your MA300 system. Please call us for current pricing and further information.

Upgrading to add additional EMG channels

The upgrade procedure is very simple. When you purchase the upgrade from Motion Lab Systems you will receive a replacement subject backpack and additional EMG preamplifier electrodes. Remove the EMG preamplifiers from the original subject backpack and plug them into the upgrade backpack. Plug the additional EMG preamplifiers that were supplied with the upgrade into the extra EMG channels. The new, upgrade, subject backpack may now be plugged into the coaxial interconnecting cable. The new upgraded backpack is now completely functional.

If the original installation anticipated that the system would be upgraded then you may find that your system already has the additional EMG channels already connected to your data acquisition system. If not you may need to connect and assign additional analog channels to record or sample the new EMG channels that have been added by the upgrade. Please contact Motion Lab Systems if you need a new analog connection cable or advice on connection the additional channels to your system. Once you are certain that the new system is completely functional you should return the original subject backpack to Motion Lab systems or your agent to complete the upgrade procedure.

Installing the MA300-F Band pass filter

You will need:

- MA300-F filter installation kit.
- A small amount of Loctite® or similar thread locking material.
- Philips screwdriver, Open wrench and Hex Allen wrench

Instructions

1. The filter card mounts inside the MA300 Desk Top Unit (DTU). Turn the DTU AC line power off and disconnect the AC line cord from the rear of the DTU. Disconnect all other cables. These are the 25-way DB-25 analog signal cable, LEMO coaxial cable and 9-way DB-9 connector (if used).
2. Move the DTU to a clean work area and find a small container to store screws and other items that you remove from the unit as you open it - you will need these when you re-assemble the DTU.
3. While facing the front of the DTU, gently lay the unit over to the left side. All access to the inside of the DTU is from the right side of the unit.
4. Remove the two black plastic feet (on your right side) from the unit by pulling them straight up to expose the recessed securing screws. Note that the front and rear feet are slightly different - place the feet to one side - you will need them to reassemble the unit.
5. Remove the two similar black plastic screw covers (on your left side) from the top side of the cover by pulling them straight up to expose the recessed securing screws. Place the two covers (front and rear) to one side - you will need them to reassemble the unit.
6. Release all four securing screws using the Philips screwdriver and place them to one side - you will need them to reassemble the unit.
7. Remove the plastic cover by lifting straight up to reveal the metal box that contains the DTU electronics.
8. The internal metal cover is secured by fourteen (14) screws - remove all fourteen screws, placing them carefully to one side - you will need them to reassemble the unit. Each screw will have a small locking washer - try and keep the washers with the screws as it will save you time later when you replace the cover.
9. Lift off the metal cover to reveal the internal electronics board and AC line power supply in a separate shielded compartment. As you lift the cover from the DTU - note that there is a small lip on the metal cover that mates with the rear panel of the DTU.
10. Remove the large ribbon cable that runs from the base of the DTU and turns at ninety degrees to a connector just above the AC power supply. The MA300-F option card will replace this signal cable.
11. Remove the cover from the HP filter switch opening at the rear of the DTU - this opening is directly above the LEMO interface connector.
12. Mount the rotary HP filter switch in the hole and route the switch wiring so that it runs underneath the top lip of the metal DTU case, towards the front of the DTU.

This completes the preparations for installation.

13. Secure the switch using the mounting hardware provided with the switch. Rotate the switch such that the switch knob aligns with the printed filter settings on the rear of the DTU.
14. Locate the two Phillips head mounting screws that are mid-line on the DTU main electronics board. One is just below the ribbon cable that connects the display card to the DTU main electronics card; the second screw is just above and to the left of the AC power supply compartment. These screws must be removed to allow the MA300-F option card to be secured to the DTU main electronics card. Check their location using the mounting holes on the MA300-F option card and remove both screws and locking washers. These two screws and washers will not be needed again and can be discarded.
15. Carefully insert the MA300-F option filter card into the two sets of connectors on the DTU main electronics card. Note that the MA300-F option connectors must align by pin numbers. Pin-1 on the filter card must mate with Pin-1 on the DTU main electronics card. Due to the differing number of pins on the two connectors this will result in the filter card appearing to have one set of connecting sockets that do not mate with any pins on the DTU main electronics card. This is correct.
16. When the filter card is inserted correctly, place the two spacers (supplied) in between the MA300-F option card and the DTU main electronics board so that they align with the two mounting holes in the two printed circuit cards. Use a small amount of Loctite® on each of the two screws (supplied) and attach the MA300-F option card to the DTU main electronics card using the spacers provided.

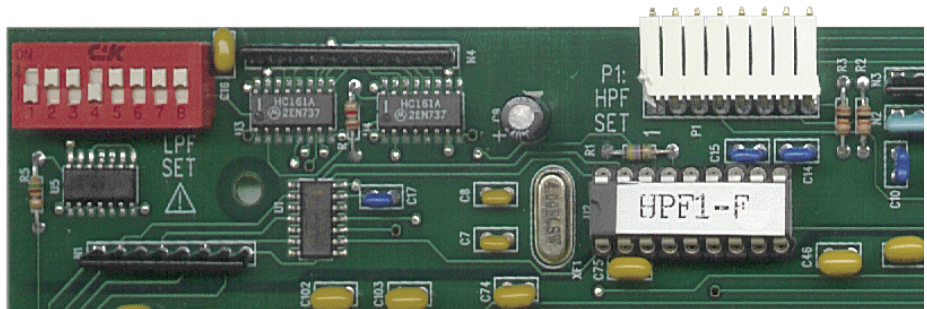


Figure 22 - Band Pass filter showing preset LP switch and HP switch connector.

This completes the functional installation of the MA300-F option card.

17. Connect the filter switch cable to the MA300-F option card. The 8-way connector is at the top of the MA300-F option card and the wires from the switch will dress into the connector from below if the connector is aligned correctly.
18. Check that the DIP switch settings for the LP filter are set to the correct values. You may wish to change the default LP filter setting depending on your EMG data collection environment.
19. Replace the metal cover that you removed in step 9, taking care to make sure that the lip is fitted against the rear cover and that the screw holes all line up.
20. Secure the metal cover to the main DTU box using the fourteen screws and locking washers that were removed in step 8.
21. Replace the plastic cover and secure using the four Philips head screws that were removed in step 6.

22. Replace the two black plastic feet, taking care to make sure that the front and rear feet are pushed into the correct holes, as the two feet are not interchangeable. Replace both of the top screw covers making sure that the front and back covers fit into the right holes.
23. Reconnect the DTU to the AC power and test the system by applying EMG signals to each EMG channel in turn and confirming that the EMG signal appears on the recording or measuring device.

The upgraded MA300 is now ready to use.

Filter Switch Settings

The optional MA300-F band-pass filter implements a sophisticated pair of separate low-pass and high-pass filters on each EMG channel. The low-pass filter settings are preset when the system is installed and cannot be easily changed by the user. This feature enables the MA300 to be configured (if desired) so that it always limits the high frequency component of the EMG signal to a value that can be handled by any external recording or measurement system. Each filter is implemented using a combination of analog and digital filters - all EMG channels are filtered at the same frequency.

The high-pass filter is user adjustable via a rotary switch at the rear of the MA300 desktop unit and supports the following filter points:

MA300-F High Pass Filter
25 Hz.
40 Hz.
60 Hz.
80 Hz.
100 Hz.
120 Hz.

The low-pass filter that is built into the MA300-F should be set to a value that depends on the maximum sampling or measuring rate that you will be using with your analog recording or measuring system. The MA300-F low-pass filter allows you to limit the high-end bandwidth of the MA300 system regardless of the setting of the subject backpack filter switch. This is especially useful in situations where the MA300 is used with a fixed clinical protocol that requires specific analog data sampling rates or where the installation engineer wishes to make sure that the EMG system cannot generate ‘out-of-band’ signals regardless of the users LP filter selection in the backpack.

The default filter frequency for the MA300-F low-pass filter is -3 dB at 2,000 Hz as shown below. Many common gait labs will select a lower frequency such as 600Hz if they are sampling data at 1,200 samples per second (i.e. 20 samples per 60Hz video frame). Switches shown as “1” are ON. The MA300-F filter setting will then override any higher value selected using the backpack switch.

MA300-F Low Pass Filter Settings			
Filter Selection	Minimum Sample Rate		DIP switch
2,000 Hz.	Default	4,000 s/sec.	0-1-1-0-1-1-1-1
1,800 Hz.		3,600 s/sec.	1-0-1-0-1-1-1-1

1,500 Hz.		3,000 s/sec.	1-1-0-0-1-1-1-1
1,400 Hz.		2,800 s/sec.	0-1-0-0-1-1-1-1
1,300 Hz.		2,600 s/sec.	1-0-0-0-1-1-1-1
1,250 Hz.		2,500 s/sec	0-0-0-0-1-1-1-1
1,200 Hz.		2,400 s/sec.	1-1-1-1-0-1-1-1
1,100 Hz.		2,200 s/sec.	0-1-1-1-0-1-1-1
1,050 Hz.		2,100 s/sec.	1-0-1-1-0-1-1-1
1,000 Hz.		2,000 s/sec.	0-0-1-1-0-1-1-1
950 Hz.		1,900 s/sec.	1-1-0-1-0-1-1-1
900 Hz.		1,800 s/sec	0-1-0-1-0-1-1-1
850 Hz.		1,700 s/sec	0-0-0-1-0-1-1-1
800 Hz.		1,600 s/sec.	1-1-1-0-0-1-1-1
750 Hz.		1,500 s/sec.	1-0-1-0-0-1-1-1
700 Hz.		1,400 s/sec.	1-1-0-0-0-1-1-1
650 Hz.		1,300 s/sec.	1-0-0-0-0-1-1-1
600 Hz.		1,200 s/sec.	1-1-1-1-1-0-1-1
550 Hz.		1,100 s/sec.	0-0-1-1-1-0-1-1
500 Hz.		1,000 s/sec.	0-0-0-1-1-0-1-1
450 Hz.		900 s/sec.	0-0-1-0-1-0-1-1
400 Hz.		800 s/sec.	0-1-1-1-0-0-1-1
350 Hz.		700 s/sec.	1-1-1-0-0-0-1-1
300 Hz.		600 s/sec.	0-1-1-1-1-1-0-1
250 Hz.		500 s/sec	0-0-0-0-1-1-0-1
200 Hz.		400 s/sec	1-0-1-1-1-0-0-1
175 Hz.		350 s/sec	1-0-1-1-0-0-0-1
150 Hz.		300 s/sec	1-1-0-1-1-1-1-0
125 Hz.		250 s/sec	0-0-0-0-1-0-1-0
100 Hz.		200 s/sec	0-0-0-1-1-1-0-0

Appendix C

Installation

The MA300 AC power supply will automatically select the correct AC line voltage – no adjustment is required.

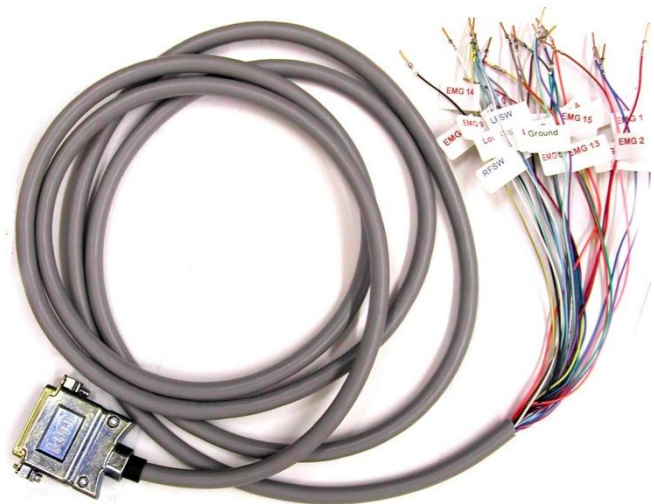
The MA300 uses a modern switching power supply that meets all international safety standards for medical equipment. It is also a “smart” power supply and will automatically set itself to the correct line voltage within any of the common ranges (100 to 240 Volts AC 50/60Hz) when the system is turned on. There is no need to open or adjust the MA300 to select an AC line voltage.

Each MA300 system is fully tested before shipment to the customer and end-user and, while we cannot guarantee that nothing will go wrong, we have found that virtually all initial problems with a new system are caused by faulty connections or miss-wiring the interface to the users analog data collection system. You can improve the chances of an easy installation by reading this appendix and carefully testing the system configuration before serious use of the MA300 with subjects.

The MA300 consists of two units (back-pack and desk-top unit) that are connected together by a lightweight RG-174/U coaxial cable. The standard system is designed to be completely self-contained and is very easy to setup and configure for use in any Gait, Biomechanics, or Motion Analysis Laboratory. It provides electrically isolated, real time analog signals from EMG pre-amplifiers placed on a subject’s skin surface, as well as other signals from optional event switches and other data channels.

In most circumstances MA300 system installation consists of connecting the supplied analog interface cable to an Analog Data Capture (ADC) or Data Recording system. This cable has a female 25-pin connector on one end and 26 free-floating leads on the other end - details of the connector pin-out are provided in

this manual. Each of the free-floating leads is labeled with an appropriate label indicating its function. This would be a good point to stop and find the analog



interface cable and examine it - you should find it packaged with a sheet of paper that provides some details of the pin to cable connections. An analog connection cable with individual BNC connectors is available on request.

The MA300 also features a female 9-pin connector on the rear panel marked “Option” (or “Display on some models). This connector supplies access to digital signals - it does not contain any analog signals and should not be connected directly to any analog data collection system.

The system installer should read the documentation that is provided with the data collection system that is to be used with the MA300 before starting the installation. Since the MA300 can be used with almost any data collection system it is difficult to provide precise and specific instructions on every installation situation. However the following issues are common to almost every situation:

MA300 Outputs

All MA300 outputs are static protected and voltage limited internally to no more than ± 5 volts. Each output is single-ended, using a common signal return point, and is driven by a current limited, low impedance source.

Signal Channels

The MA300 system can support different numbers of signal channels that may contain specific data. It is not always possible to translate MA300 channel numbering to use identical data collection channel numbers. Make sure that the system user knows what MA300 channels are connected and which channels the data collection system uses to record or display EMG, Event Switch and Research Data.

Note that the standard analog signal cable is supplied with connections for all sixteen analog channels even when the system has fewer EMG channels. If at all possible it is recommended that all sixteen channels are connected when the system is first installed as this will make any subsequent upgrades much easier if the user decides to upgrade the system at any time.

Ground

Also known as “Signal Return” - it is vital that the MA300 Ground is connected to the Analog ground (or signal return) of the users data collection system. Failure to connect the MA300 Signal Return will result in crosstalk and noisy signals. Most initial data quality problems are caused by poor (or non-existent) ground connections.

Data Parity

This is a TTL level signal that indicates any problems with the digital data transmission. In most circumstances it can be ignored or connected to an unused analog channel. If connected to an analog channel it will have a level of between 4.75 to 4.95V when EMG and other signals are being transmitted without any errors. Do not connect this signal to any analog ground.

MA300 Case

This is connected to the MA300 case. It is an electrical ground for the metal case and should be connected to the chassis or safety ground of the data collection system. In many cases this can be connected to the analog signal ground. If problems occur with AC interference or excessive noise in the EMG signal then this connection can be moved to the Signal Return Ground (above), the AC line ground, the chassis ground of your data recording system or disconnected.

Shield

This is a connection to the shield of the signal cable supplied with your MA300 system. It should be connected to the data collection system analog signal ground. Its function is to provide electrical shielding for the analog data signals in the MA300 cable. This lead does not make any electrical connection to the MA300. It is not a substitute for the Ground connection.

Configuration

If you are not familiar with the data measurement, or data collection system, that you are using then this is a good place to stop and read the manuals that were supplied with the data collection or recording system that you are planning to use.

Once the MA300 analog cable has been connected to the your data collection system it is a good idea to start up the data collection system and setup the data collection parameters before applying power to the MA300. In general there are two parameters that you will need to check - these are input signal level and sample rate.

Signal Level

All analog signals generated by the MA300 are in the range of ± 5 volts so you need to set the analog data collection system to record data or accept input signals at this level. If you select a lower level (i.e. ± 2.5 volts) then the MA300 signals may be clipped or distorted and will not be measured correctly. If you select too high a level (i.e. ± 10 volts) then the measured signals will be too small and you will lose some resolution or precision.

Sample Rate

The simple rule of thumb for setting the analog data collection sample rate is to always sample the data at twice the rate of the highest frequency present in the signal. Since the maximum bandwidth for MA300 systems with a variable low pass filter is DC to 2,000 Hz this would require a very high sample rate (a minimum of 4,000 and preferably at least 5,000 analog samples per second per channel) unless the signal is filtered to remove the higher frequency components. This is normally done by setting the anti alias, low pass filter on these systems to a suitable value. Most of the signal power from surface EMG is lower than 350 Hz so setting the backpack filter to 350 Hz reduces the analog data recording requirements considerably if all of the EMG data is limited to surface recordings. The system user will usually know what signal bandwidth is required.

It is a good idea to allow for some degree of over-sampling when you set the analog sample rate so if you were setting the backpack LP filter to 350Hz then a sample rate of between 700 and 1000 samples per second per channel would be appropriate.

Some MA300 systems have a fixed DC to 1000Hz bandwidth – these systems must be sampled at a rate of 2000 samples per second per channel or faster.

Testing

Once the MA300 system is connected you will need to make some test recordings or measurements to confirm that the system is (a) operational and, (b) working correctly with your analog measurement system. So connect the system to the AC line using the power cable supplied and turn on the power:

- a) If the MA300 is operational then you should see a green Power Status light turn on. If the backpack is not connected to the desktop unit (or is not

functioning correctly) then you will also see the amber No Signal (No.Sig) and CRC lights turn on. If the backpack is connected and functioning correctly then both of these lights will be off - disconnect the backpack and you will see them both turn on. When the backpack is connected you should also see a green light on the backpack indicating that power is reaching the backpack. This sequence of operations checks that all major systems within the MA300 are functional.

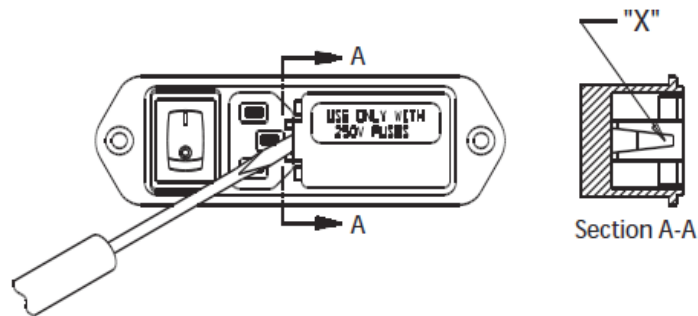
- b) Check that the system is working correctly by connecting a single EMG electrode to channel one and using it to make a test recording. Check that the EMG signal is recorded on the correct channel and not any other channels of the analog data measurement system. Check all the EMG channels in this way to verify the MA300 EMG channels are connected to the correct analog channels on the users system. If you find any errors then correct them and restart the test from channel one.

If you are using event switch channels then connect the event switches to the backpack and check their operation using the green front panel lights that indicate event switch closure. Check that the correct DC levels are recorded by the users analog data collection system and that they are recorded on the correct channels - make sure that the left and right sides are connected and labeled correctly as getting these swapped can confuse any subsequent data analysis.

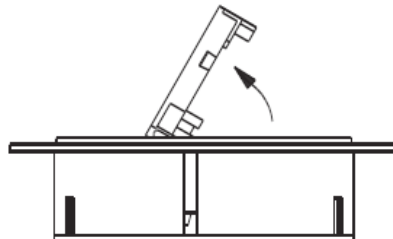
When connected correctly the MA300 should provide many years of trouble-free service. Please contact Motion Lab Systems if you have any questions about either the installation information provided or the operation of the MA300 system.

Changing the Fuses

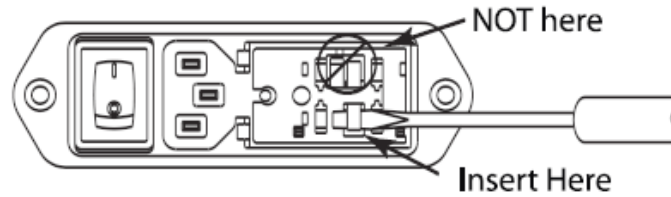
1. Insert a pocket screwdriver at point "X" as shown. Gently lift UP until the entire door lifts up approximately 1/4" (minimum).



2. Once lifted, the door will pivot on its hinges and expose the fuse holder.



3. When the fuse holder is installed in the single fuse position, apply the screwdriver as shown and gently pry up. Use screwdriver as shown, do not use fingers.

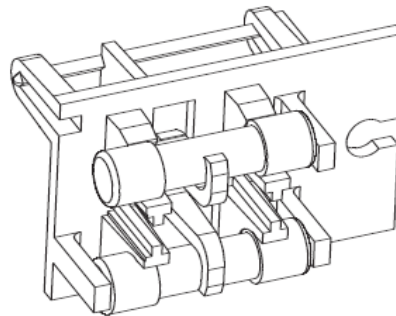


When the fuse holder is installed in the dual fuse position, it will normally release as soon as the door is opened.

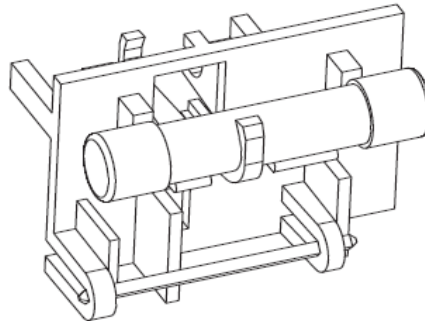
Fusing Options

The MA300 supports both US and European fuses – it is supplied configured for European fuses.

European Fusing Arrangement**



North American Fusing Arrangement**



**Install fuses on one side only. Do Not install both AG and Metric fuses at the same time.

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